ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ98-472(1)

UNIVERSITY RESEARCH CENTER PHASE 1

Final Report

Prepared by:
Vicki Walker
2640 W. Wolf Street
Phoenix, AZ 85017

July 1998

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation or the Federal Highways Administration. This report does not constitute a standard, specification, or regulation. Trade or manufacturer's names which may appear herein are cited only because they are considered essential to the objectives of the report. The U.S. Government and the State of Arizona do not endorse products or manufacturers.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-AZ-98-472(1)		

4. Title and Subtitle	5. Report Date
University Research Center Phase I	July 1998
	6. Performing Organization Code
7. Authors Vicki Walker	8. Performing Organization Report No.
9. Performing Organization Name and Address Vicki Walker 2640 W. Wolf St. Phoenix, AZ 85017	10. Work Unit No.
	11. Contract or Grant No. SPR-PL-1-(53) 472
12. Sponsoring Agency Name and Address **ARIZONA DEPARTMENT OF TRANSPORTATION** **206 S. 17TH AVENUE** **PHOENIX, ARIZONA 85007** Project Manager: John Semmens	13.Type of Report & Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes
Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

The Arizona Department of Transportation Research Center has become separated from its connections with the three in-state universities. In an effort to re-establish a productive relationship with the universities, a survey of state transportation departments and university research centers was conducted in an attempt to determine what organizational structures are currently used and which would best serve Arizona's needs.

The diversity of models used indicates that there may be no one best way to conduct transportation research. Therefore, the "best" model is the one which is developed by the entire local transportation community to fit its needs and which is adaptable over time.

The success of state DOTs in soliciting private sector participation was explored as a means of procuring additional sources of research funds. Over 75% of the survey respondents indicated they have some private sector involvement in their program; however, most private sector involvement is in the form of materials, equipment, and services, rather than monetary contribution which ranged from 1% to 18% of annual research budgets.

Since the private sector does not account for a large portion of a center's budget, funding sources initially come from state legislatures, the DOTs, and/or the university(s). Many states indicated that the transportation center is highly dependent upon the DOT to supply research projects for approximately the first five years. During this time, the center's reputation is expanded and its ability to attract outside funding and projects from other sources increases. The funding provided by the DOT does not need to be large; however, a constant among all states which have productive cooperative programs is the continuity of funding. A commitment must be made by the DOT to sustain a level of support which is sufficient to elicit a similar commitment on the university's part to devote faculty and other resources to meet the DOT's research needs.

17. Key Words	18. Distribution Statement	23. Registrant's Seal
transportation research centers	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161	

19. Security Classification	20. Security Classification	21. No. of Pages	22. Price
Unclassified	Unclassified	202	

ACKNOWLEDGEMENT

The author would like to thank the many helpful people from transportation agencies and universities who provided the information which formed the basis for this report. In addition to those individuals who took the time to answer the questionnaire, the following are very much appreciated, as well as nameless others who helped to point in their direction.

Arizona Department of Transportation

Tricia Lindley (602-255-7604)
Erika Martinez (602-256-9431)
Frank McCullagh (602-407-3132)
Larry Scofield (602-407-3131)
John Semmens (602-407-3137)

Arizona State University

Mathew Betz, Ph.D. (602-488-7954)
Elizabeth Burns, Ph.D. (602-965-7533)
Terrie Ekin (602-965-1721)
Sandra Houston, Ph.D. (602-965-2790)
Mary Kihl, Ph.D. (602-965-6693)
Jonathan Upchurch, Ph.D. (602-965-1713)

Colorado Department of Transportation

Richard Griffin (303-757-9973)

Iowa State University

Tom Maze, Ph.D. (515-294-8103)

Northern Arizona University

Steve Nix, Ph.D. (520-523-4339)

University of Arizona

Muni Budhu, Ph.D. (520-621-2145)

Washington State Department of Transportation

Marty Pietz (360-705-7974)

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares .	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3

		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

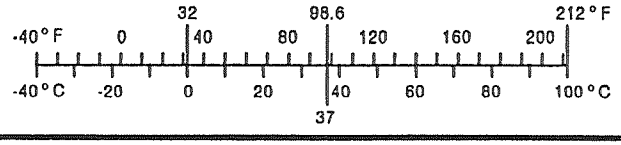


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Arizona Department of Transportation Research Center has become separated from its connections with the three in-state universities. In an effort to re-establish a productive relationship with the universities, a survey of state transportation departments and university research centers was conducted in an attempt to determine what organizational structures are currently used and which would best serve Arizona's needs. In addition, several other questions were asked of survey respondents regarding their transportation research activities.

Six models of DOT/university relationships are used by the 41 states that responded to our survey:

- 4 states (10%) have a research center located at a university;
- 6 states (15%) contract primarily with only one university;
- 15 states (37%) contract with multiple universities;
- 1 state (2%) requests bids from consultants and universities;
- 1 state (2%) conducts all research in-house at the DOT; and
- 14 states (34%) use some other process which is generally a combination of the above methods (Arizona is among these states).

The diversity of models used indicates that there may be no one best way to conduct transportation research. Therefore, the "best" model is the one which is developed by the entire local transportation community to fit its needs and which is adaptable over time. The location of the transportation research center is largely dependent upon the model chosen. Situating the center at one university or at several has both advantages and disadvantages, although the disadvantages can be minimized through continual communication among the parties involved.

The benefits of a close working relationship between the DOT and universities included access to specialized knowledge and equipment available within the university environment, research cost-effectiveness, opportunities for both parties to become familiar with the other's motivations and needs, real-world experience for university faculty and students, and increased opportunities for technology transfer.

The importance of establishing a cooperative research agreement between the state DOT and the universities was stressed by many survey respondents. In a survey conducted by the National Cooperative Highway Research Program, 33 of 42 states responding to the survey (79%) reported having some type of basic agreement, which is not a contract with the university, but rather an understanding between the state and the university.

The success of state DOTs in soliciting private sector participation was explored as a means of procuring additional sources of research funds. Over 75% of the survey respondents indicated they have some private sector involvement in their program; however, most private sector involvement is in the form of materials, equipment, and services, rather than monetary contribution which ranged from 1% to 18% of annual research budgets.

Estimating the budget requirements for a university transportation research center is dependent upon the model used in establishing the center. Since the private sector does not account for a large portion of a center's budget, funding sources initially come from state legislatures, the DOTs, and/or the university(s). Many states indicated that the transportation center is highly dependent upon the DOT to supply research projects for approximately the first five years. During this time, the center's reputation is expanded and its ability to attract outside funding and projects from other sources increases. The funding provided by the DOT does not need to be large; however, a constant among all states which have productive cooperative programs is the continuity of funding. A commitment must be made by the DOT to sustain a level of support which is sufficient to elicit a similar commitment on the university's part to devote faculty and other resources to meet the DOT's research needs.

INTRODUCTION

Arizona has three state universities: Northern Arizona University (NAU) located in Flagstaff, Arizona State University (ASU) located in Tempe, and the University of Arizona (UA) located in Tucson. Over the years, the Arizona Department of Transportation (ADOT) Research Center has become separated from its connections with the in-state universities. ADOT has come to realize that this situation may not be advantageous for either themselves, the university community, or the private sector. Many successful transportation research centers in other states appear to have strong connections with their state universities. Re-establishing a relationship between ADOT and the universities could be a means of improving the quality of Arizona's transportation research. Additionally, employing more university students in ADOT research projects could offer many advantages: ADOT could save considerable money on needed research work; students could expand their education into "real life" situations; and training opportunities could be provided for undergraduate and graduate engineering students who could be future ADOT employees.

Phase I of this project involved attempting to determine the best organizational structure for a new relationship between ADOT and the universities by examining the working relationships between other state DOTs and their in-state universities. This report offers a synthesis of information obtained from: (a) annual reports of state transportation departments and university research centers and various other literature; (b) responses to a questionnaire which was submitted to all state transportation departments and universities who are members of the Council of University Transportation Centers (CUTC); and (c) interviews with individuals at ADOT, ASU, NAU, UA, and researchers in other states. The individuals interviewed are listed under the acknowledgement section at the end of this report.

An overview of the various methods which the DOTs use to conduct research is presented. Consideration is given to how a university transportation center might improve research results and how it might enhance learning about transportation. The advantages and disadvantages of locating the center at a single university or at more than one university are discussed, as well as the advantages and disadvantages of establishing a cooperative agreement among all three universities to promote transportation research and learning. In an effort to seek additional funding sources, how other state research centers solicit and obtain private sector involvement and funding, and whether this funding can be sufficient to make the research center self-sustaining is addressed. Estimates are also provided of the cost and funding sources necessary to establish a transportation research center at one of Arizona's state universities.

Data from the survey are used throughout the synthesis. A sample of the questionnaire is shown in Appendix A. A list of those state transportation departments and university research centers who responded to the questionnaire is shown in Appendix

B. A summary of the information provided by individual respondents is given in Appendix D, as well as individual respondent contact information for those who wish to obtain additional information about a particular state's program.

HISTORY

In the early 1980s, the research arm of ADOT, the Arizona Transportation Research Center (ATRC), sought to establish a closer working relationship with its in-state universities. They used the Virginia research center as a model, in which the Virginia Department of Highways and Transportation research director and his staff were housed in a research facility built by the Department on the campus of the University of Virginia at Charlottesville. Virginia's research program was developed and implemented by the Virginia Highway and Transportation Research Council, which was jointly sponsored by the Department and the University. [1] At about the same time, ASU's College of Engineering and Applied Sciences established four Engineering Excellence Programs, one of which was the Center for Advanced Research in Transportation (CART).

In 1983, an intergovernmental agency agreement was established between ADOT and ASU. The goals of the new relationship were to provide funded research to Arizona's universities, offer graduate students an expanded education with "real world" research experience, and provide training for students who could be employed by ADOT upon graduation. The agreement directed ADOT to fund four graduate students, one faculty-man-year of release time, and provide for overhead. No set amount of research was to be directed to ASU, as Arizona's Private Enterprise Law required that any research over $10,000 be advertised. This required that ASU bid on ATRC research projects along with other universities and private sector firms.

The ATRC and CART were co-located in the Engineering Research Center on ASU's Tempe campus. The centers were housed on separate sides of the same floor with shared lab space. This close proximity of the two facilities allowed for direct day-to-day contact which led to a very close working relationship. The two directors often sat in on the other's meetings, and CART personnel were often consulted for technical advice on projects in which they may not be a contracted researcher. Sharing lab space also allowed CART to keep ATRC informed of the progress for those projects which were awarded to ASU.

During the early 1980s, most of the research by an in-state university was done by UA in Tucson. However, according to ADOT personnel, much of this research was not implementable, and contract difficulties caused the ATRC to be disillusioned with UA. By the end of the 1980s, the ATRC/CART relationship had proven to be very successful, and ASU was conducting more research. In 1988, when the first CART director left the center, ASU had close to $1 million in active contracts.

The late 1980s and early 1990s marked a period of upheaval in the ATRC/CART relationship. As stated previously, the CART director left the center in late 1988 and was replaced by an interim director until a permanent replacement was found in early 1990.

In 1991, the center changed its name to the Center for Advanced Transportation Systems Research (CATSR) to more accurately reflect the multi-disciplinary nature of its research. At about the same time, the ATRC director was replaced with a new director, and the reporting relationship of the ATRC within ADOT changed from the Highway Division to the Transportation Planning Division.

Both new directors were extremely interested in securing federal monies for research into Intelligent Transportation Systems (ITS), and a proposal was written to attract this research and establish a facility at ASU's Research Park located south of the main Tempe campus. This funding was not realized; however, ADOT had entered into an agreement to relocate to the Research Park and felt they must honor that contract when their lease in the Engineering Research Center expired. ASU was also experiencing space shortages on campus which helped encourage the ATRC's move. The move resulted in a reduction of space for the ATRC from approximately 10,000 square feet in the Engineering Research Center to roughly 4000 square feet at the Research Park facility.

In late 1991, the CATSR director was once again replaced with an interim director until a new director was hired in early 1994. There was a change in the Civil Engineering Department Chair (1989) and several changes in the Dean of the Engineering College (1987, 1989, 1991, 1992, 1994, 1995), as well. These changes in addition to the ATRC's move off the main ASU campus saw increased tensions in a relationship which was already becoming strained. The ATRC was experiencing dissatisfaction with the timeliness of the research done, and did not feel they were receiving the desired product from CATSR. This, combined with ATRC's earlier disillusionment with UA, led to a loss of confidence in universities as a whole. During this time as well, ADOT was experiencing slimming measures which resulted in a loss of several positions within the ATRC. The ATRC reporting structure within ADOT was transferred back to the State Engineer's Office, and a change in funding sources resulted in the ATRC moving to their current ADOT facility in downtown Phoenix when the contract expired at the ASU Research Park in 1996. The relationship between ADOT and the state universities had become nearly non-existent at this point, and most research contracts were being awarded to private consultants or out-of-state universities. When the CATSR program came up for review by the Engineering Dean in 1996, funding was not renewed and the program was discontinued. According to the ATRC, university-related individuals currently participate in 11 of 34 projects (32%) which account for 21% of funding.

Another casualty of the break between ADOT and ASU was the Arizona Local Technology Transfer Program, or the T2 Program. The T2 Program was administered by the CATSR and was partly funded by the Local Transportation Assistance Program (LTAP) which began in 1982 as the Rural Transportation Assistance Program (RTAP). T2 centers were created by the Federal Highway Administration (FHWA) to provide technical training and assistance to governments, cities, and towns which had a population of less than 50,000 persons. In 1991, the program was expanded to include cities with up to one million in population, and the name was changed to LTAP. The

CATSR T2 Program provided presentations of a variety of transportation training workshops, distribution of training videocassettes, distribution of publications, and provision of technical field assistance state-wide. [3] By 1996, the annual cost of this program was over $300,000 and ADOT did not feel the level of service was commensurate to the cost when compared to similar programs in other states. A three-day partnering conference was held to rectify the problem; however, when the contract expired in 1996, the T2 Program was moved from ASU to ADOT for administration.

Interviews of individuals involved with the ATRC and the CATSR programs provided several suggestions as to why the relationship between ADOT and ASU failed. The primary cause expressed by many was a lack of communication by both parties. Changes in leadership at all levels in both organizations contributed to confusion and loss of a joint focus, as well. The move of the ATRC from ASU's main campus to the Research Center was suggested as a pivot point; however, relations were already becoming strained by that time. Although the move led to a physical distancing which prevented the closeness enjoyed when the centers were first established, it was felt this could have been overcome if the prior close "mental" relationship still existed. Relations currently continue to be strained, but ADOT and all three universities have expressed a desire to re-establish a closer relationship. The earlier success of the ATRC/CATSR relationship is pointed out by an increased national standing by the late 1980s, and the success of many graduate students currently located around the country who had the opportunity to participate in research through the early phases of the program, one of whom is the current director of the ATRC.

SURVEY

The first phase in the goal to re-establishing a relationship between ADOT and the three state universities involved determining the "best" organizational structure for the new relationship. One method for accomplishing this involved conducting a survey of the working relationships between other state DOTs and their in-state universities. Since a relationship involves at least two parties and the perceived success of the relationship by each party was of interest in this study, the survey included the transportation departments in 49 states (excluding Arizona) and university research centers who are members of the Council of University Transportation Centers (CUTC). The CUTC was established in 1979 by the major transportation research centers and institutes in the United States and promotes continued dialogue among its member institutions, as well as providing a forum for the centers to interface collectively with government and industry. One CUTC goal is to strengthen the role of transportation research and education, both inside and outside the university environment. [4] The 1997 CUTC Member Roster listed 49 active member centers in 28 states. [5]

A questionnaire was developed in order to ascertain the type of relationship or organizational structure existing in each state and the advantages and disadvantages of that structure. Recipients were asked what they would change about their current relationship if they could. Information was also requested regarding whether there is any private sector involvement and funding of the research program, and if so, a description of any solicitation process used. Recipients were asked whether this private sector funding allowed the research to be self-sufficient. Finally, additional comments were requested which the recipient felt they could offer to benefit ADOT's research into the relationship/organizational structure between a state DOT and the state universities for the purpose of conducting transportation research.

Two versions of the questionnaire were distributed - one to state DOTs and one to the university research centers. The questions were virtually identical with wording changed only regarding whether the recipient was a DOT or research center. Samples of the questionnaires are shown in Appendix A.

A listing of the respondents is shown in Appendix B. Thirty-four state DOTs responded for a response rate of 69 percent. Twenty-eight responses were received from the research centers out of 52 surveys sent. (Some research centers had more than one individual listed in the membership roster and surveys were sent to everyone listed.) This gave a research center response rate of 54%. The overall response rate was 61% and responses were received by at least one organization in 41 states which provided representation from 84% of the country.

When the questionnaires were returned, the answers were summarized in a database for ease in analyzing the results. Individual responses were printed on a

questionnaire response form. A sample form is shown in Appendix C, and individual responses are given in Appendix D.

The response form indicates the state where the organization is located, the name of the organization, and the name, phone number, e-mail address, and postal mailing address of the respondent. These are provided so interested parties may contact those individuals for further information regarding their program. Boxes are checked regarding the DOT/university relationship(s) used by that organization. Abbreviations are explained as follows:

1. URC indicates that the DOT has a research center located at a university

2. ONE UNIV indicates the DOT contracts with one university for research

3. MULT UNIV indicates the DOT contracts with multiple universities for research

4. BIDS CONS/UNIV indicates that DOT research is offered for competitive bids from universities and consultants

5. DOT indicates that research is all done in-house with DOT personnel

6. OTHER PROCESS indicates that some process other than those listed above is used

A brief description of the process used is shown, along with advantages and disadvantages of the current process, and changes the respondent would like to see to that process. If private sector funds are a part of the research program, the box under "PRIVATE SOURCE FUNDS" is checked followed by a description of private sector involvement and an indication of whether these funds allow the center to be self-sufficient. Additional comments offered by the respondent are summarized at the bottom of the form. Any question which was not answered is indicated by "None Given" on the response form.

Data obtained from survey responses are used throughout this report.

RELATIONSHIP MODELS

In a National Cooperative Highway Research Program (NCHRP) survey conducted for the Transportation Research Board (TRB) in 1995, states reported on the size of their DOT research staff, the number of projects currently in progress, and where the research for those projects was being done. They also reported on their solicitation process. The following table shows a breakdown of their responses. [6]

Table 1. 1995 NCHRP DOT Survey Data

STATE	DOT RESEARCH STAFF	TOTAL 94-95 PROJECTS	PROJECTS BY CATEGORY *					SOLICITA-TION PROCESS **
			CONS	UNIV	PF	SELF	OTHER	
AZ ♠	9	34	17	11	-	6	-	RFP
AL	5	32	-	27	2	2	1	RFP-UNIV
AK	1	36	1	31	-	4	-	RFP-UNIV
AR	14	48	-	13	4	30	1	RFP-UNIV
CA	35	134	14	44	21	55	-	RFP
CO	14	69	10	13	10	36	-	RFP, SS
CT	26	54	3	15	7	25	4	RFP
DC	1	8	-	1	3	4	-	RFP-UNIV
FL	4	130	2	96	30	-	2	RFP-UNIV
GA	11	53	4	25	5	19	-	RFP
ID	1	21	1	8	10	2	-	RFP-UNIV
IL	32	34	-	12	-	22	-	RFP-UNIV
IN	25	77	1	58	3	15	-	RFP-UNIV
IA	8	47	7	21	-	15	4	RFP
KY	1	54	-	54	-	-	-	RFP-UNIV
LA	46							RFP-UNIV
ME	15	15	-	11	1	2	1	RFP-UNIV
MD	10	16	-	6	4	6	-	RFP-UNIV
MI	60	139	1	36	7	95	-	RFP-UNIV
MN	12	123	35	88	-	-	-	RFP, SS
MS	14	17	1	3	-	13	-	RFP
MO	22	31	-	7	2	22	-	RFP-UNIV
NE	2	53	-	14	21	18	-	RFP-UNIV
NV	1	9	-	7	2	-	-	RFP-UNIV
NH	3	12	1	3	2	4	2	RFP
NJ	16	63	9	6	8	40	-	RFP
NM	6	11	2	7	-	1	1	RFP
NY	41	60	-	14	17	28	1	RFP-UNIV

STATE	DOT RESEARCH STAFF	TOTAL 94-95 PROJECTS	PROJECTS BY CATEGORY *					SOLICITA-TION PROCESS **
			CONS	UNIV	PF	SELF	OTHER	
NC	6	24	-	23	4	1	3	RFP-UNIV
ND	4	31	1	-	3	27	-	SS
OH	18	73	11	39	20	-	3	RFP
OR	11	76	1	12	9	54	1	RFP
PA	8	80	20	11	14	35	-	RFP
RI	5	11	-	7	-	4	-	RFP-UNIV
SC	4	18	1	11	4	2	-	RFP
SD	9	48	8	5	2	33	-	RFP
TN	1	31	-	31	-	-	-	RFP-UNIV
TX	16	200	-	200	2	-	-	RFP-UNIV
UT	12	18	4	14	-	-	-	RFP
WA	8	101	2	83	16	-	-	RFP-UNIV
WV	5	25	-	25	-	-	-	RFP-UNIV
WI	8	70	-	28	15	27	-	RFP-UNIV
WY	3	24	3	5	6	10	-	RFP, SS
TOTAL PROJECTS BY CATEGORY			143	1114	254	651	24	
PERCENT PROJECTS BY CATEGORY			6.5%	51.0%	11.6%	29.8%	1.1%	

* CONS=Private Consultant; UNIV=University; PF=Pooled Fund; SELF=In-House Staff; OTHER=OTHER
** RFP-UNIV=Request for proposal from universities only; RFP=Request for proposal from all; SS=sole source
[a] AZ data is for fiscal year 1998 and is for comparison purposes only. AZ is not included in the total calculations.

Source: NCHRP Synthesis of Highway Practice 231 Managing Contract Research Programs

As can be seen by this table, the vast majority (80.8%) of projects were conducted either by a university or by in-house DOT staff. In addition, 57% of the state DOTs reported issuing a request for proposals to universities only.

The survey conducted by ADOT attempted to expand on the NCHRP survey by determining the primary model used by each state DOT to conduct their research. The models identified are: (1) the DOT has a research center located at a university; (2) the DOT contracts with one university for research; (3) the DOT contracts with multiple universities for research; (4) DOT research is offered for competitive bids from universities and consultants; (5) DOT research is all done in-house by DOT personnel; and (6) some other process or combination of processes is used. Although most states actually use several of these processes, the model indicated as being used primarily by each state is shown in Figure 1. In cases where different processes were indicated by the state DOT versus the university(s), an attempt was made to classify the state process as that most likely, given the combined descriptions from the questionnaire responses.

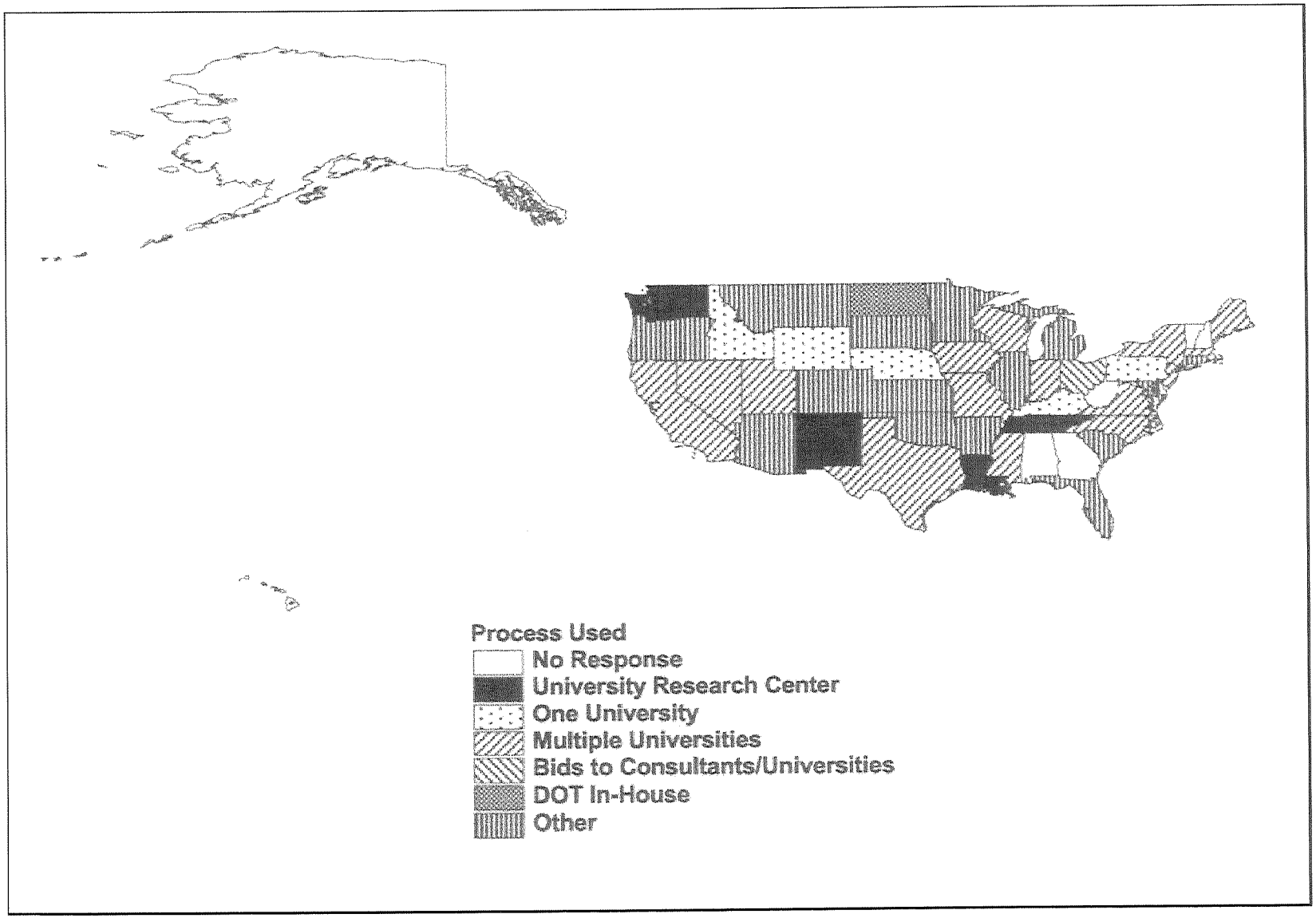
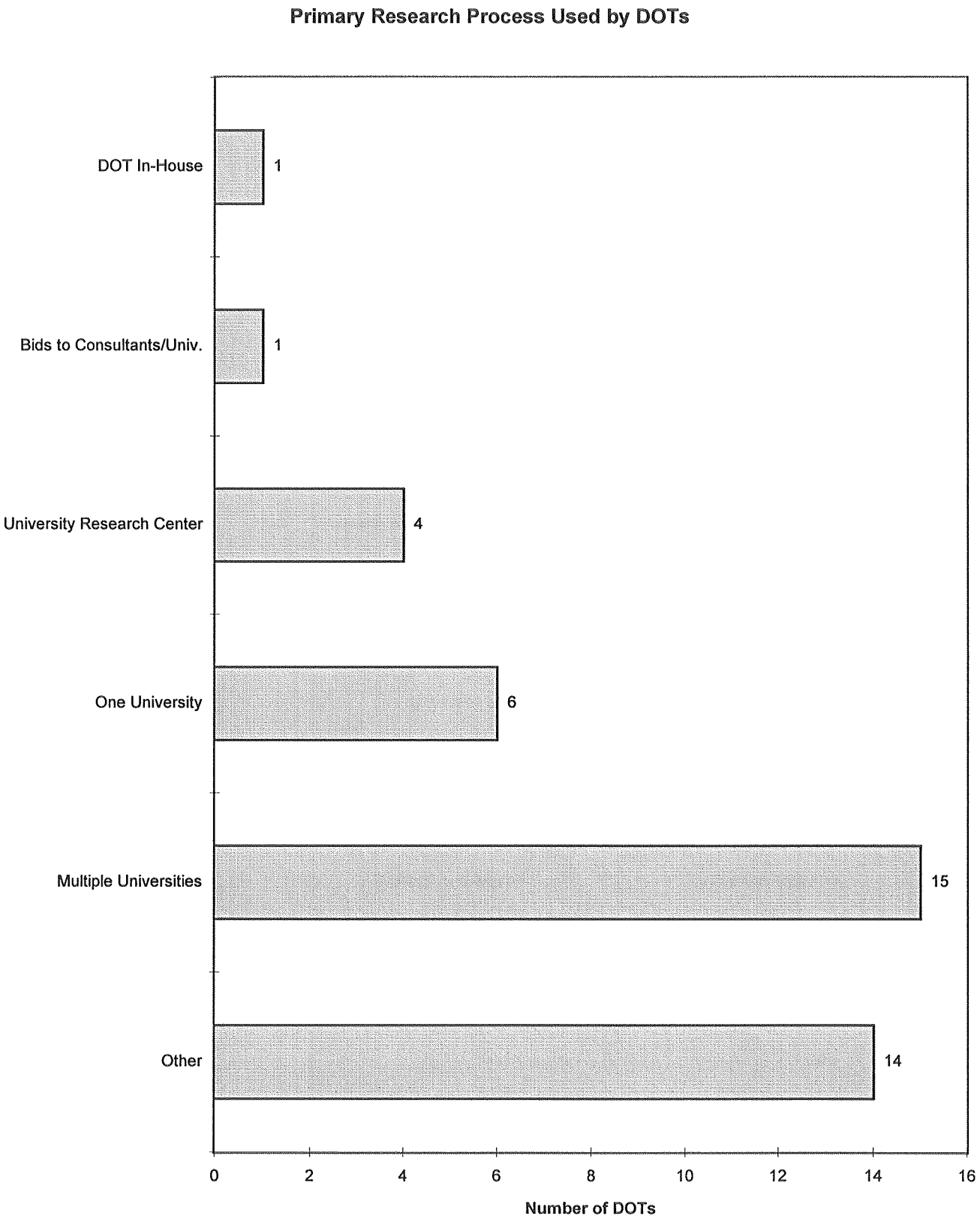


Figure 1. Indication by State of DOT Research Model Used

Of the 41 states represented in the survey responses, the primary method of conducting research is as follows: 4 states (10%) use the university research center model; 6 states (15%) contract with only one university; 15 states (37%) contract with multiple universities; 1 state (2%) requests bids from consultants and universities; 1 state (2%) conducts all research in-house at the DOT; and 14 states (34%) use some other process for conducting DOT transportation research. This breakdown is shown in Figure 2. In summary, 25 of 41 reporting states (62%) have a primary method of conducting research that involves university. This survey finding confirms information reported in the NCHRP survey.

Figure 2


Primary Research Process Used by DOTs
DOT In-House
1
Bids to Consultants/Univ.
1
University Research Center
4
One University
6
Multiple Universities
15
Other
14
0
2
4
6
8
10
12
14
16
Number of DOTs

Although each state has been categorized as primarily using a particular model, the exact procedures followed by state often vary. A description of each of the six models is given below with a summary of some states' procedures for each model.

UNIVERSITY RESEARCH CENTER

All universities who are members of the CUTC have transportation research centers associated with their university; however, this model refers to the relationship of the state DOT conducting its research through a specific university research center with which it has some type of joint administration or agreement. Four respondents in the survey indicated this type of relationship (Louisiana, New Mexico, Tennessee, and Washington). Since these state models vary significantly, all four are summarized.

Louisiana

The Louisiana Transportation Research Center (LTRC) is jointly administered by the Louisiana Department of Transportation and Development (DOTD) and Louisiana State University (LSU), but is a budget entity of the DOTD. The LTRC was created by the Louisiana Legislature in 1986 and is largely supported through funding from the Federal Highway Administration and the Louisiana DOTD. LTRC expenditures for 1995-96 were $6,443,000 ($4,223,000 for research and development and $2,220,000 for technology transfer and training).

LTRC is located on the LSU campus in a 25,300 square foot facility containing five research laboratories, a classroom, a conference room, and offices. The facility houses 30 students and more than 60 employees, of which 67% are DOTD employees and 33% are LSU employees. The LTRC director is a DOTD employee and a gratis LSU employee which is considered essential to their success in terms of targeting applied research which can be implemented. Approximately 50% of the DOTD's research is conducted by the LTRC. The other 50% is contracted with seven in-state universities for areas needing external expertise.

The LTRC Policy Committee advises and makes recommendations to the LTRC concerning research and technology transfer programs, budgeting, and policies of the center. The committee meets at least twice a year and is composed of ten members: three appointees of the secretary of DOTD, one appointee of the chancellor of LSU, six appointees from other state universities, the director of LTRC, and an FHWA appointed observer.

No disadvantages were cited by the LTRC. The only changes they would like to make would be that the LTRC director should report to the Secretary of DOTD. They would also like to restructure the internal units and upgrade positions in order to attract DOTD personnel to the LTRC who have experience in operational areas.

New Mexico

The New Mexico State Highway and Transportation Department has co-located its research bureau with the research center at the University of New Mexico, the Alliance for Transportation Research Institute (ATR). This allows for quick exchange of information, and the ability to address research issues and respond to opportunities.

After several unsuccessful attempts at various other models by both the DOT and the state universities, it became apparent that the largest transportation research centers in the state were the national laboratories which conducted defense research. The ATR was established in 1992. It is a unique partnership comprised of the DOT, New Mexico State University, the University of New Mexico, Los Alamos National Laboratory, and Sandia National Laboratories.

The ATR has what they call a "loose-tight" partnership. The premise is that when the partner organizations want to act in concert they have an effective means of doing so, and when they want to work independently, the partnership is flexible enough for that as well. The only stipulation is that a partner wishing to work independently on a project must inform the rest of the partnership beforehand in order to avoid confusion.

Prior to the ATR's formation, the DOT funded approximately $250,000 for civilian transportation research which was provided 80% by federal funds with a 20% match in state funds. Since the formation of the ATR, an average of $15 million has been attracted annually, with significant projects 100% federally funded.

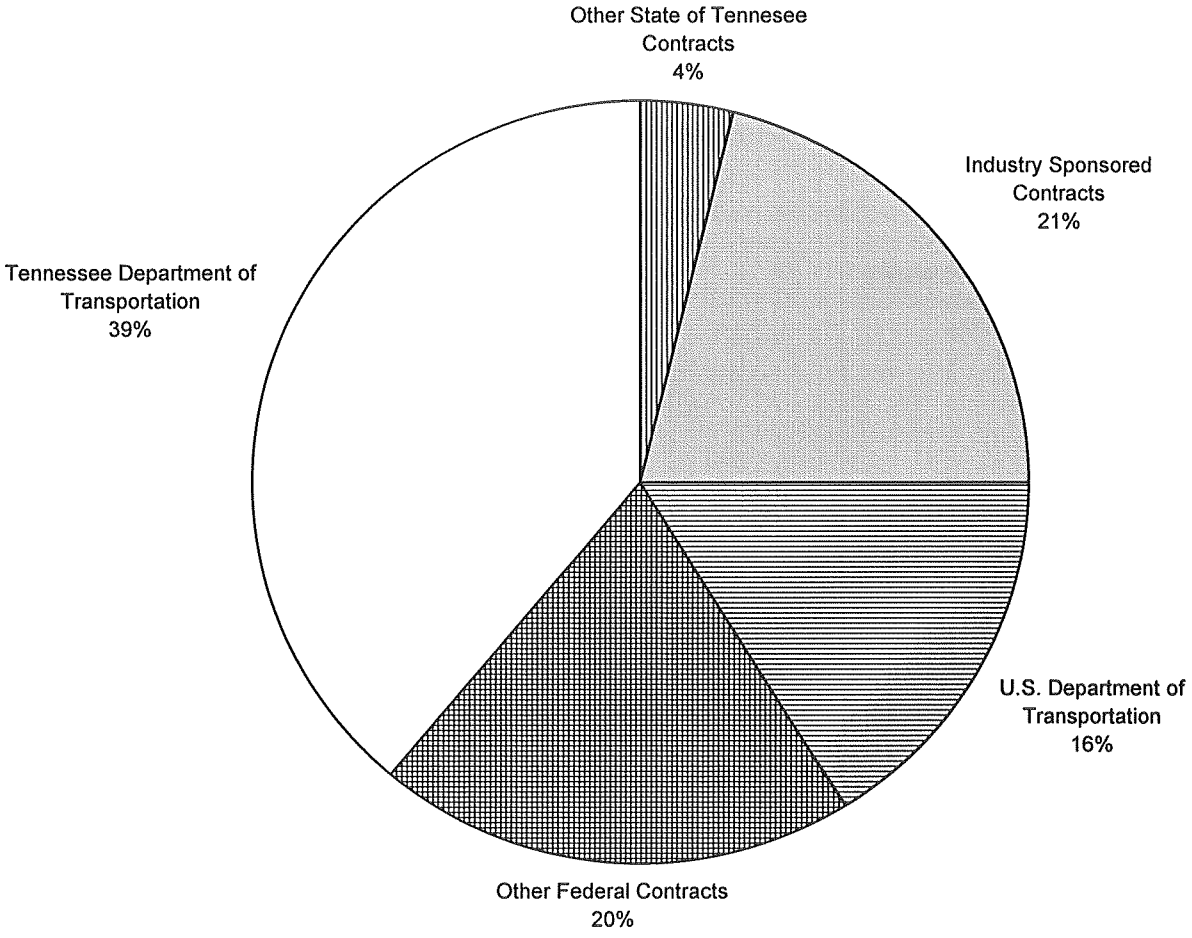
The ATR has published report number FHWA-HPR-NM-92-03 which describes in detail the steps taken to establish this partnership. It includes the successes and failures over the last five years, and presents the ATR's goals for the future which include incorporation as a separate entity and funding self-sufficiency.

Tennessee

The Tennessee Department of Transportation (TDOT) has essentially no research department, but has a formal agreement which is state law for the University of Tennessee (UT) to administer its transportation research program. An advisory committee comprised of members from the TDOT division head level consider problem statements and then forward those selected to UT. UT is then responsible for developing the request for proposal (RFP), awarding and executing the contract, managing the financial and technical matters, and meeting the deadline. The UT transportation center has a full-time staff member who oversees administrative functions and works closely with the TDOT research coordinator, the university, and other TDOT business offices involved. TDOT feels this arrangement allows them flexibility in awarding contracts, while putting the burden of managing those contracts on UT. Total new grants and contracts for fiscal year 1995 were $6,712,758. A breakdown of these funding sources is shown in Figure 3.

Figure 3

Tennessee Research Center Funding Sources



Neither TDOT nor UT cite disadvantages with Tennessee's process. However, responses from other universities indicate they receive very little research and that they must "court" TDOT in order to be awarded a contract or have a project approved for research. Changes which state universities would like to see include creating a research center within TDOT and formalizing the procedure to solicit and consider research problem statements which are generated outside and independent of TDOT. Establishing a schedule for generation, evaluation, and awarding projects in order to maximize involvement by both TDOT and researchers is also desired.

Washington

The Washington State Transportation Center (TRAC) is a cooperative transportation research agency comprised of the University of Washington (UW), Washington State University (WSU), and the Washington Department of Transportation (WSDOT). TRAC acts as a liaison connecting those who need applied research at WSDOT and those best suited for conducting it at the universities.

The executive board consists of the secretary of WSDOT and the vice provost from each of the universities. Each agency is able to appoint one director. The executive director is currently from WSDOT with co-directors from UW and WSU. In effect, there is a research center located at each agency with the official TRAC office residing at the location of the executive director. Each director is an employee of both TRAC and their respective organization, but they have not found joint reporting to be a problem. TRAC has established a presence in each location by funding support staff to assist with report preparation, for which each university contributes $30,000 and WSDOT contributes $60,000.

A solicitation process for prospective research projects is conducted every two years by WSDOT. Anyone can submit a problem description; however, the selection committee does not include university or private sector representatives. Successful proposals tend to be those sponsored by WSDOT rather than those desired by the universities or private sector. The problem descriptions are sorted by probable emphasis area. A workshop for each emphasis area is convened to rank the potential projects by urgency, benefit/payoff, probability of success, and complementary factors such as availability of funding outside of WSDOT's research budget. The workshop committees contain representatives from the Federal Highway Administration (FHWA), WSDOT executives, line engineers from affected areas, and the WSDOT regions. The ranked potential projects are next placed in a funding matrix, by rank within their emphasis area rather than a single list. The Research Executive Committee approves the final program based on available funds. Those projects which are actually undertaken are either issued a task order to one of the two universities or an RFP from consultants and other in-state and out-of-state universities. Approximately 85% of research is conducted by either UW or WSU with the majority going to UW, and the other 15% is conducted via RFP. A technical monitor has oversight of each research project to keep it on track.

When TRAC was originally established in the early 1980s, research project funding was primarily from WSDOT; however, growing national recognition has provided other funding sources. During the 1993-1995 period, TRAC researchers were involved in 125 projects with

budgets totaling over $14.1 million and expenditures of $10.1 million, not including administrative costs. Funding support during that same period came from the Strategic Highway Research Program (SHRP), the U.S. Department of Transportation, the FHWA, the Federal Transit Administration (FTA), the TRB, the National Science Foundation, and the U.S. Forest Service. Other public supporters included the Washington State Energy Office, King County Metro Transit, the Puget Sound Regional Council, and Snohomish County Public Works. Private supporters and contributors included PACCAR, Chaparral Systems, ERES Consulting, Urban Systems, Inc., and Cambridge Systematics. In addition, TRAC was involved in research partnerships with the Michigan State and Louisiana State departments of transportation.

WSDOT uses this organization model primarily for ease in contracting and the ability to establish a presence at UW and WSU. The process has enabled the three organizations to establish a long-term relationship and has helped the universities to understand WSDOT needs. The task order process allows executing research requests quickly. WSDOT foresees no change in the current procedure. Examples of WSDOT's interagency agreement, basic agreement, and task order format are shown in Appendix G, H, and I, respectively.

CONTRACT WITH ONE UNIVERSITY

Six states reported that they contract primarily with one university (Hawaii, Idaho, Kentucky, Nebraska, Pennsylvania, and Wyoming). Five of these states (Hawaii, Idaho, Kentucky, Nebraska, and Wyoming) use this process due to the small size of the DOT research staff and/or limited access to universities with graduate engineering programs in their states.

Hawaii performs some research in-house; however, the university offers expertise and equipment which the DOT does not have for many areas of transportation research.

The Idaho Department of Transportation (IDOT) research staff consists of only 1½ people, so the majority of research contracts are with the University of Idaho, although a small number are awarded via requests for proposals (RFP) from consultants and other universities. IDOT would like to develop better in-house capability for support and publication of some projects which are being performed in-house, but are currently undocumented due to lack of staff.

The Kentucky Department of Transportation conducts all research through the Kentucky Transportation Center (KTC) located at the University of Kentucky. A research coordinator (currently the assistant to the state highway engineer) acts as liaison between the Kentucky Cabinet and the university. The Cabinet has a research program and implementation advisory committee which is responsible for study selection and general oversight of the program.

The Nebraska DOT (NDOT) contracts primarily with the Mid-America Transportation Center at the University of Nebraska at Lincoln (UNL), although they occasionally seek competitive bids. NDOT cites advantages to their relationship including the development of a good working relationship, and improved and expanded testing facilities at UNL in order to accommodate a wider spectrum of research activities. The main disadvantage seen is the

tendency for research to be academia-driven with little accountability for quality. NDOT would like to see changes to include stressing the need for research which can be implemented, rather than something "which is just a good topic for a graduate student thesis".

The Wyoming Department of Transportation (WYDOT) performs administrative oversight only, with most research performed by the University of Wyoming (UW) and a small portion awarded to private consultants. They do not currently have an official RFP process which has led to an exclusive relationship with UW that does not foster competition. As the result of a recent peer exchange process, WYDOT plans to add one or two individuals to the WYDOT research staff and develop a more structured RFP process.

Pennsylvania

Until five years ago, the Pennsylvania Department of Transportation (PennDOT) bid all research projects. In 1993, PennDOT entered into a partnership agreement with the Pennsylvania Transportation Institute (PTI) located at Pennsylvania State University (Penn State). According to the agreement, PennDOT matched grants received by Penn State, which currently amounts to approximately $300,000 annually for each organization. During this five-year period, PennDOT-funded research to PTI has grown consistently and now totals nearly 40 percent of PTI's externally funded research activities. Effective early 1998, PennDOT and PTI have negotiated a broader, long-term collaborative agreement whereby PTI will become the single point of contact to coordinate all university-based research, education, and technology transfer (T2) activities sponsored by PennDOT. It is estimated that PTI will perform approximately 75 percent of the research, and universities outside of Pennsylvania will perform the rest. The new agreement is valued at $15 million over the next five years.

CONTRACTS WITH MULTIPLE UNIVERSITIES

More than one-third (37%) of the states reported contracting with more than one university for their transportation research. These states include California, Indiana, Iowa, Maine, Massachusetts, Mississippi, Missouri, Nevada, New Jersey, New York, North Carolina, Texas, Utah, Virginia, and Wisconsin. All of these states (with the exception of Nevada) have relatively large DOT research departments and reportedly conduct some research in-house (see Table 1), although they report that the out-of-house research relationship is with multiple universities.

The advantages for conducting research through several universities rather than with just one university are: (1) the wide variety of expertise available; (2) the ability to handle a large research workload; and (3) the ability to match the capabilities of an individual university with the project requirements. Another advantage is the competitiveness which is engendered through issuing RFPs to more than one university, although several states report limited competition for research (e.g., California, Indiana, Iowa, Maine, Missouri, and Nevada). [6]

Chief disadvantages with this relationship model include: (1) over-reliance on the universities to develop research problem statements and proposals; (2) less in-house research

staff available to address the immediate needs of DOT departments; (3) considerable DOT time spent managing the research program and monitoring progress; and (4) lack of broad-based representation on the research advisory committees.

Changes the DOTs would like to implement include: creating a co-op research program; creating a partnership agreement allowing better identification of research needs, development, and implementation; and implementing a process to develop internally-proposed problem statements for which an RFP could be issued.

Summaries of several programs are given below.

California

The California DOT (CALTRANS) funds the university research centers located at the University of California campuses at Berkeley, Davis, and Irvine. CALTRANS sees this association as providing multiple sources for both bids and contracts with multiple participants providing good diversity. They also cite short-term availability of very specific expertise on specific projects. Most projects are considered interactive rather than just contract management by CALTRANS. The universities agree that the master agreements provide strong relationships between CALTRANS and themselves, as well as facilitate funding and easy access to researchers. However, they report a lack of coordination between the various arms within CALTRANS. This overlapping of various CALTRANS departments has at times led to competition for funding which can be self-defeating. The universities would like to see more coordination within CALTRANS, as well as an annual conference which involves all academic units and DOT units in order to establish the agenda for the upcoming year and improve communications among all groups.

Indiana

Indiana has a unique situation in that even though research is conducted by several universities, state legislation enacted in 1937 requires that all proposals be reviewed by the Joint Transportation Research Program (JTRP) located at Purdue University. The JTRP advisory board consists of nine Indiana Department of Highways (IDOH) representatives, nine Purdue representatives, one FHWA representative (non-voting), and four highway industry representatives (non-voting). The advisory board solicits problem ideas from IDOH personnel at an annual meeting and then meets approximately monthly to review written proposals and approve projects. [1]

Iowa

The Iowa DOT (IDOT) has had a long-standing relationship with the Iowa universities since the early 1900s. The Iowa Highway Research Board was created in 1950 to promote, review, and recommend funding of research. The board now includes six county engineers, three IDOT engineers, the deans of the engineering colleges at Iowa State University (ISU) and the University of Iowa (UI), and three engineers representing Iowa cities. In 1996, IDOT and the

three state universities (ISU, UI and the University of Northern Iowa) entered into the Iowa Transportation Collaboration Agreement. This agreement identified the mechanisms for the university community to participate and support IDOT's research management process, as well as identifying an active role for the universities in defining the state's transportation research agenda. In 1997, IDOT and ISU's Center for Transportation Research and Education (CTRE) entered into two long-term agreements. The first is a basic agreement which allows CTRE to support IDOT in developing new initiatives, quick-response information gathering, and areas of assistance to IDOT which are not included within the scope of an existing project. The second agreement is an umbrella agreement known as the Research Management Agreement which allows IDOT to initiate research projects with ISU through a one-page addendum to the umbrella. These agreements are presented as examples in Appendix F.

One of the arrangements developed under the umbrella agreement is the joint hiring of the director for CTRE who is also a research faculty member and is paid jointly by IDOT and ISU. This collaboration between IDOT and ISU also allows IDOT engineers to teach classes for ISU students and ISU staff to conduct workshops for IDOT employees and others. The agreement has the flexibility to allow IDOT to contract with any of the three state universities, as well as allowing CTRE to contract with other state DOTs.

Massachusetts

The Massachusetts DOT (MDOT) previously had a blanket contract worth $900,000 annually with the university research center located at the University of Massachusetts. They recently chose not to renew this agreement because the university has three campuses and they found that MDOT got better results dealing directly with each campus individually rather than using the university research center as the "middle man". MDOT's research policy is very strict due to reduced availability of funds; therefore, they only conduct applied research which will help solve a current problem or condition.

Texas

The Texas transportation research program is one of the largest, oldest, and most highly regarded programs in the country. Many states have attempted to copy its tenets, and others have come to believe that the program cannot be duplicated in any other state. In either case, the program offers many examples for success.

The Texas Department of Highways (TDOH) first contracted with Texas A&M in 1917. In 1950, the Texas Transportation Institute (TTI) was established, and in 1963, the Center for Transportation Research (CTR) at the University of Texas entered into contract with TDOH as well. In the past, nearly all TDOH research has been conducted at these two universities; however, outside pressures have recently opened the research up to 22 state universities. TDOH feels this allows for competition and improved products, as well as bringing real world problems to all the universities. The two original universities, however, feel it has weakened the cooperative partnership which they previously enjoyed with TDOH. Even so, both TTI and CTR cite advantages in the current program as being stability and continuity of funding, active

research involvement at all levels of TDOH, support for students and faculty, preparation for future employees of TDOH, and lower overhead costs for TDOH by working with the universities. No changes are anticipated in this proven system.

COMPETITIVE BIDS FROM UNIVERSITIES AND CONSULTANTS

Only the Ohio Department of Transportation (ODOT) responded as conducting all research solely on bids from universities and private consultants. Ohio has 13 in-state universities with engineering programs which ODOT feels promotes competition and reasonable prices, as well as making it easy to find expertise in any area. Using this process makes more knowledge and equipment available for research, and decreases ODOT staffing and operating costs. Students are exposed to practical engineering problems, and the low cost of student labor decreases the cost of labor-intensive research. Small research projects which need immediate attention are carried out through "special student studies" which have a maximum cost of $10,000 and a maximum of 12 months duration.

The main disadvantage ODOT finds is that researchers sometimes don't understand the problem being researched. ODOT finds it difficult to change the direction of the research, and problems or errors may go undetected. With so many universities in addition to private consultants conducting research, ODOT also finds it difficult to monitor progress of ongoing research projects. They also believe that research funding which is spent on private consultant profits doesn't benefit research and could be spent more productively at the universities.

ODOT would like to see more ODOT involvement in the areas of technology transfer and implementation. Currently, "hands on" knowledge gained during research stays with the university or consultant, without being passed on to ODOT employees.

IN-HOUSE

Currently, only the North Dakota Department of Transportation (NDDOT) conducts the majority of its research in-house, which is primarily in the area of materials testing. A research advisory committee allows the Upper Great Plains Research Center at North Dakota State University (NDSU) the opportunity to suggest and submit research projects for inclusion in NDDOT's budget. NDDOT would like to see more dialogue between themselves and NDSU in order to allow the university a better understanding of the type of research which NDDOT can utilize.

OTHER

The remaining 14 states responding to the survey (34%) reported their DOT/university relationship as something other than those five relationships previously described, although some of the programs in this category are similar to those in other categories. The majority reported using a combination of university contracts, solicitation of bids from universities, and/or conducting some research in-house. Only four of the states (Maryland, Oklahoma, Oregon, and South Dakota) also report soliciting bids from private consultants. The process currently used by

Arizona falls into this category along with those of Arkansas, Colorado, Connecticut, Florida, Illinois, Kansas, Maryland, Michigan, Minnesota, Montana, Oklahoma, Oregon, South Carolina, and South Dakota.

Advantages of using a combination of research sources include the flexibility to contract with well-qualified researchers regardless of their affiliation, access to a large number of transportation research personnel allows the best researcher to be matched to the particular project, in-house personnel provide continuity on long-term projects, and projects which require a solicitation process have a well-defined scope and expected product stated.

The primary disadvantage stated is the time required to start the project due to the RFP and contract negotiation process. Multiple contracts also require considerable time spent by the DOTs on administrative functions. Following are descriptions of the model used and comments for a few states.

Arizona

The research division of the Arizona DOT (ADOT) is the Arizona Transportation Research Center (ATRC). Each year, the ATRC solicits ideas on ADOT's transportation research needs. Those which are the most highly regarded and urgently needed (as determined by customer feedback) are forwarded to the ADOT research council, a committee made up of ADOT's division heads and top management, for funding consideration. Selected ideas are developed into research projects which are either performed by the ATRC or awarded via solicitation of bids to universities or private consultants. University-related individuals currently participate in 11 of 34 projects (32%) which account for 21% of funding. Most research contracts have been awarded to private consultants (67% of funding and 50% of projects).

Colorado

In 1992, the Colorado DOT (CDOT) formed the Colorado Transportation Institute which was established as a joint public-private-university cooperative transportation research unit involving CDOT and five state universities. A copy of the memorandum of understanding is shown in Appendix E. This agreement was not renewed when it expired due to lack of response from the universities. The current process which CDOT uses involves solicitation of bids from consultants and multiple universities, or in-house use of research specialists. CDOT feels this process allows them to tap into national expertise, gain access to expertise and equipment which CDOT does not have, and focus resources for quick turnaround. In addition, maintaining a quality staff of CDOT researchers facilitates implementation and project management. CDOT did not cite any disadvantages with their current process; however, they would like to streamline the contracting process and would like to once again develop a cooperative agreement with the state universities.

Florida

The Florida DOT (FDOT) created its research center in 1989 with the idea that research funding should be available to all functional areas of FDOT, each Florida university should have an equal opportunity to compete for FDOT research funding, research initiatives should address identified needs (applied vs. basic), the program should concentrate on state rather than national issues, and that information regarding all research results should receive a wide distribution. FDOT's research center maintains a small staff and does not perform any in-house research, although some strength and materials testing is done in-house at labs which are not administered by the center. The research center has an annual budget of approximately $6 million and awards 25-35 new contracts per year with about 130 active contracts.

A key component of FDOT's research strategy is the use of professionals throughout FDOT to serve as research project managers. FDOT feels that not centralizing project management at the research center allows the research to be managed and the results to be implemented at the working level of each office. This strategy also promotes ownership of research which assists the implementation process and also allows the professionals to maintain active involvement in new and developing technologies. To ensure that all research needs are being adequately considered, FDOT formed a technical research advisory committee made up of 22 employees representing each of FDOT's eight district offices and functional work areas. The committee's primary duty is to review research needs and balance them to available funding. Proposals must be submitted by an FDOT employee so universities must have a willing sponsor to have their proposals considered.

Research is conducted primarily at Florida's seven state universities, with approximately 15% awarded to private consultants, other state agencies, and out-of-state universities. Contracts are either awarded directly to universities without competition based on a proven record and expertise or offered for solicitation of bids. The decision as to which process is used is up to FDOT staff depending on the project. Awarding contracts directly avoids wasted time when a proven researcher is available; however, all projects require an individual contract. This requires considerable and repetitive administrative functions which could be eliminated or reduced by establishing a master task-order contract with the universities. Overall, FDOT and the universities appear happy with the current process and anticipate no changes.

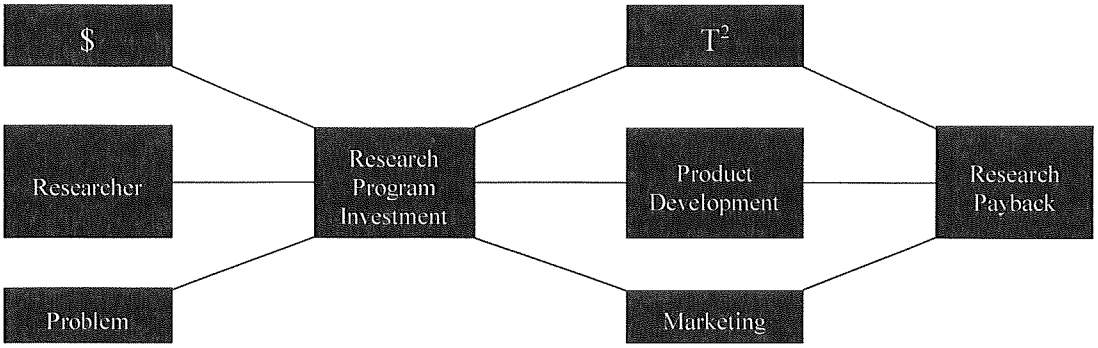
Kansas

The Kansas DOT (KDOT) conducts research through their in-house research program and through contracts with the two major state universities, Kansas State University (KSU) and the University of Kansas (UK). A cooperative transportation research program was created during 1990 between KDOT, KSU, and UK. The program is called the Kansas Transportation Research and New-Developments (K-TRAN) Program, and was modeled after the Texas program. The annual K-TRAN Program budget is approximately $500,000. Each university is guaranteed from $100,000 to $250,000 which funds graduate students and faculty. The overall benefit to cost ratio in July 1996 was 30.7:1, and some K-TRAN funds are used as matching funds for Mid-America Transportation Center (MATC) projects which further leverages their

research dollars. In addition, KDOT does not pay indirect costs to the universities as a result of state legislation. Both KDOT and the universities find the program to be highly successful. The only change anticipated is the merging of the K-TRAN technical committee and the research steering committee so that one committee will oversee the technical aspects of both university and in-house research.

Minnesota

Transportation research in Minnesota is conducted through a combination of Minnesota DOT (MnDOT) in-house research and contracts through multiple universities. All university research, however, is coordinated through the Center for Transportation Studies (CTS) at the University of Minnesota (UM). Having only one research university in Minnesota makes the process simpler and has the advantage of a strong university/DOT relationship in terms of both organizations understanding the other's culture. MnDOT is represented on both the CTS executive committee and the research councils. MnDOT finds the use of both internal and external sources broadens the scope of expertise available, stimulates the discussion and debate on research questions, and minimizes the consequences of dependency on a sole source. The flexibility and range of subject matter which MnDOT researches requires a greater investment in the program and considerable management support. MnDOT is known for having an administration that values research as a process which provides continuing education of all staff and new employees in the long-term. To this end, the users of the research are expected to participate throughout the project for mutual learning by both the user and the researcher. A flowchart of MnDOT's research process is shown in Figure 4.



Source: Minnesota Department of Transportation, Transportation Research 1995 Annual Report

Figure 4. Minnesota Research Process

The process begins with problem identification which directly affects the potential for the project's implementation. The problem statement is then matched with funding and the desired researcher to create the research program investment. Completion of the research leads to the implementation process which includes education of users through the Technology Transfer (T2) program, and product development and marketing if appropriate. The process concludes with the effective application of research results and an identifiable benefit to MnDOT and its customers.

RESEARCH IMPROVEMENTS

Regardless of the type of research relationship maintained between the state DOT and their university(s), the sole reason such a relationship is established in the first place is to conduct transportation research. The quality of the research product is of utmost significance. It is important, therefore, to ascertain how conducting research through a university research center might improve the DOT's research results.

Shuldiner's findings in the late 1980s suggested that while it was not necessary for a strong highway agency research program to be conducted in conjunction with a university, the two usually seemed to go together. It was also found that where a close, long-standing relationship existed between the state highway agency and a university, not only was the agency's research program strong, but the university's highway education, research, and public service programs were strong as well. [1] This correlation appears to hold true today. University research programs which have total grants in excess of $2 million yearly are also programs which have strong relationships with their state transportation department. According to the financial summaries in the 1995 CUTC Member Profile [4], as well as data obtained from the survey conducted by Arizona's DOT, these centers include the states of California, Florida, Kentucky, Louisiana, Massachusetts, Michigan, Minnesota, New Mexico, North Carolina, Pennsylvania, Tennessee, Texas, and Washington. Not surprisingly, these universities also have strong relationships with their state transportation departments.

Although the benefits realized by the DOTs varied with the type of arrangement maintained with the state universities, several themes were commonly expressed.

- A major benefit to the DOT in maintaining a collaborative arrangement with a university is access to the specialized knowledge available at the university. This knowledge is not limited to specific disciplines within the university, although a wide range of disciplines is available (e.g., civil engineering, construction, geography, geology, business, planning, social sciences, etc.). Of equal benefit, is the general knowledge and experience of university faculty in developing and conducting research. University faculty are generally up-to-date on the latest research methods and provide access to national expertise if needed. Universities are, by nature, research institutions; state DOTs generally are not.

- Ongoing, sustained relationships between DOTs and universities allow the university research programs to grow and gain national exposure. While the DOT may prove to be a major source of funding for initial development of the university program, subsequent growth allows the university to attract other sources of funding which eases the dependence of the university on the DOT. This growth and national standing is important in attracting top researchers and students to the university program, as well as adding

research equipment and expanding facilities, which in turn provides an improved research product to the DOT.

- Universities provide the potential for flexibility in hiring highly qualified technical professionals on a temporary basis. This can benefit DOT research in several ways. University faculty and/or graduate students can meet rapidly changing needs for which research positions within the DOT are not available. Universities can also make use of "visiting professors" (professors from another university), other professionals, or collaborations with other universities and/or private industry to assist in research projects for which their on-staff faculty may lack the necessary expertise or manpower.

- Universities are considered by many state DOTs to be the most cost-effective means for conducting research, partially due to the availability of student research assistants. For example, Kansas cited a 30:1 return on research dollars spent, and Ohio pointed out that since available research funds are limited, using those funds on private consultant profits would not appear to be of benefit to research.

- Established contractual relationships between the DOT and university allow less complicated, time-consuming contract negotiations when awarding research projects. This reduces the time required prior to beginning the project. Specified responsibilities and monitoring procedures also ensure deadlines are met and project goals are achieved, thereby benefitting the final research product.

- Finally, one of the most significant and most frequently expressed benefits of maintaining a close relationship between the DOT and the university is the opportunity for both organizations to become familiar with the other's motivations and needs. Day-to-day involvement allows quick exchange of information, and the ability to address appropriate research issues. University faculty and students are exposed to "real life" issues and can understand the DOT's need to conduct applied research which can be implemented. On the other hand, DOTs can begin to understand the university's need for some "theoretical" or basic research which could prove beneficial to the DOT in the long-run. This mutual understanding and frequent contact can also lead to successful completion of research projects by the desired due date and change of direction during the research if deemed necessary.

Combining the best of both DOT and university researchers can only serve to strengthen the resulting research and offset any weaknesses inherent in either organization in order to produce the best research product available.

EDUCATIONAL BENEFITS

The primary goal of any research project is to become more knowledgeable about the particular situation which generated the initial problem statement; therefore, education is inherent in the research process. DOTs conducting research in conjunction with a university enrich the learning experience for all parties involved.

The first group to increase their knowledge about transportation is the student population. This includes both undergraduate and graduate students, and it is for the education of this group that universities exist. The traditional education experience for many students involves training in the basic tenets and theories of their field of interest. The students graduate and enter the workforce with this basic understanding, but no "real world" experience, and it is left up to the employer to continue their education in the specific areas important to that employer. Cooperative research between the university and the DOT can bridge this gap and provide the student with the opportunity to work on projects which are relevant to the real world. This not only benefits the student, but allows the DOT to have some influence in the training of potential future DOT employees. ADOT, for example, has expressed the desire for the addition of classes such as design cost estimating and project management accounting. An established relationship would allow these needs to be made known to the universities which could then respond by incorporating these needs into the curriculum. Some states (e.g., Iowa) commonly have DOT staff members as guest lecturers and instructors. The interdisciplinary nature of many research projects also allows the student to be exposed to other university disciplines in a team situation which is also a real world experience that may not occur in a traditional education program.

A secondary benefit to the student is the financial support which they receive by working on a research project. This opportunity for increased education and financial support for the student has a side effect for both the university and the DOT, as well, by allowing the university to compete more effectively for top students which serves to enhance the final research product. The ability of the university to attract top students as a result of a cooperative research environment applies to university faculty also. Drawing top researchers not only improves the research conducted, but allows the students to be taught by some of the best in their field.

The association of the university and DOT can serve to provide educational opportunities for the university faculty. Diverse research projects can expand their expertise in research, and a close relationship with DOT personnel will provide an increased understanding of DOT problems, needs, and motivations. This, again, is an exposure to the "real world" which can be beneficial to the university faculty. It can also ease some of the difficulties experienced by the DOTs who require applied, implementable research, and often times are unable to relate this need to the universities.

Those at the university are not the only participants to benefit from a cooperative research relationship. The DOT and its employees are the benefactors of increased education, as well. Continuing education of its staff is expected by many DOTs, as expressed by the Minnesota

DOT. A partnership with academia allows the DOT to benefit from the expertise and research methods of the university faculty. Allowing the DOT user to follow a research project from its inception to its implementation provides valuable training in new methods and technologies, and requiring the researcher to also follow the project to completion has added educational value for them as well. As with the university faculty, an ongoing, close relationship allows the DOT staff to understand the motivations, needs, and interests of the universities. Acknowledging that the university must conduct some basic research has led some DOTs (e.g., Texas) to fund a small portion of this basic research in addition to its more pressing applied research. After all - all applied research began with some basic research somewhere in its history. This mutual understanding leads to improved communication between both organizations.

TECHNOLOGY TRANSFER (T2) PROGRAM

The Local Technology Transfer Program, or the T2 Program, is partly funded by the Local Transportation Assistance Program (LTAP) which began in 1982 as the Rural Transportation Assistance Program (RTAP). T2 centers were created by the Federal Highway Administration (FHWA) to provide technical training and assistance to governments, cities, and towns which had a population of less than 50,000 persons. In 1991, the program was expanded to include cities with up to one million in population, and the name was changed to LTAP.

Technology transfer is recognized by many states as an important part of its operations because research dollars are wasted if research clients are unaware of the results, unable to understand the findings, or unable to implement them. In addition to publishing research reports, the findings can be included in a national database so that research efforts are not duplicated. Finally, research results must be communicated to those users who can benefit from the findings. This is accomplished by conducting training through the T2 or LTAP Program (the names are used interchangeably).

T2 programs are not involved solely with the communication of current research results. They can also offer ongoing training and certification programs which are often required by state regulations. This centralization of a state's training needs makes the best use of training resources and funds, and provides training to small communities which may have difficulty conducting it themselves.

Training is accomplished in a variety of ways, often depending on the available funding. Many states offer workshops and classes which can be conducted at a central location or taken to the user in rural areas. Videos and various publications are also maintained in a central library for use by interested parties. Other states combine classes and workshops with technology to offer state-wide video conferencing (e.g., Iowa) and national satellite teleconferencing (e.g., Minnesota). Most training is offered to DOT staff, local governments, and private industry; however, some programs are now training international customers as well (e.g., Massachusetts Institute of Technology).

How many T2 programs are administered by universities and how many are administered by DOTs was not determined by ADOT's survey; however, of the 28 states with CUTC research

centers, 80% conduct T2 training through one of those universities. [4] Some T2 programs offer free training to local governments (e.g., Arizona), and others indicate the program is nearly self-sustaining through registration fees and workshop sponsorships (e.g., Florida).

Arizona's T2 program is currently administered by ADOT through the Arizona LTAP Center. The Center offers publications and the following classes/workshops:

- Value analysis/value engineering
- Highway plan reading
- Highway plans quantities
- Traffic signals and lighting
- Pavement management multi-year prioritization
- Basic survey
- Streetscape in urban and rural environments
- Effective disaster recovery techniques
- Project management
- Fundamentals of MicroStation
- Best management practices
- Work zone traffic control/flagger training
- Signing/pavement marking
- Integrating GIS and intelligent transportation systems
- Using asset management systems to protect your investment
- Roadway condition awareness
- Roadway condition awareness
- Traffic engineering fundamentals for non-traffic engineers

These workshops are conducted around the state and some can be down-linked to local community colleges. Workshop registration fees are $50 to private industry, $25 to ADOT staff, and free to local governments (except in the case of a no show when there is a $50 "no-show" fee). The LTAP Center is currently creating a database of over 1000 workshops which are available. It is anticipated that the entire list will be accessible on ADOT's web page by the end of 1998.

RESEARCH CENTER LOCATION

The decision as to whether a transportation research center should be located at one in-state university or at more than one university is largely dependent upon what model is used to establish the DOT/university relationship. Successful programs have been established using both formats. Advantages and disadvantages of both situations are given below.

ONE UNIVERSITY RESEARCH CENTER

DOTs which conduct research primarily through one university fall into three main categories - the research center is a DOT entity, but is located on a university campus (e.g., Louisiana); the DOT has established an agreement with one university research center to administer the DOT's research program (e.g., Indiana, Minnesota, Pennsylvania, and Tennessee); or the DOT conducts research with only one university as in the "contracts with one university" model described earlier. The one university model is used in most cases due to limited engineering programs within the state rather than a choice to use only one university. If the research center is a DOT entity, it basically has control over the research conducted and procedures followed just as if the center were located in-house. Therefore, the following advantages basically pertain to the university research center as the administrator of the DOT research program.

- The DOT has one point of contact for all research projects so administrative tasks are minimized.

- A very close relationship is often developed between the DOT and the university.

- Requiring the university research center to be responsible for monitoring the status of all research projects (whether performed at their university or at another location) allows better research oversight for the DOT and minimizes its administration of projects.

- Administrative costs can be lower if DOT staff is minimized and this function is transferred to the university center for a negotiated contract amount.

Disadvantages with conducting most DOT research through one university location are as follows:

- The university research center can come to expect the bulk of DOT research to be conducted by itself.

- Unless the DOT and the university have a long-established relationship, the DOT may want to monitor where research projects are awarded to ensure the university is acting in the DOT's best interest.

- Strong relationships are difficult to maintain with other universities which may conduct research projects, but are not the main DOT contact.

- Other universities can feel that the university with the "DOT" center receives unfair advantage which can affect the overall DOT/university relationship.

MULTIPLE UNIVERSITY RESEARCH CENTERS

There is currently no example of a DOT maintaining research centers which are DOT entities at more than one university. DOTs which contract through multiple university research centers can be separated into two main categories - those which have formed a state research program (e.g., Washington's TRAC or Kansas's K-TRAN) which administers the DOT's research, but is in effect located at the DOT and the universities; and those states which have entered into basic agreements with multiple state universities (e.g., California, Florida, and Texas). The advantages of such a program are as follows.

- The DOT has a wide variety of expertise from which to choose when awarding research projects.

- The DOT can award research to the university center with the most expertise or available manpower for a particular project without resorting to the time-consuming RFP process.

- Multiple centers maintains a competitive environment regardless of whether awards are issued based on expertise or an RFP process.

- The proximity of centers located throughout the state can address the needs of those DOT agencies located nearby more quickly if not required to go through the administrative channels.

- Universities scattered in large states (e.g., California and Texas) which have differing environments throughout the state may be better able to address a research need relating to their particular geographic area.

Disadvantages with having multiple university research centers are as follows.

- Providing administrative funding for many locations can be cost prohibitive unless a nominal staff is funded in order to maintain a presence such as in Washington's TRAC.

- Several research center locations require more administrative time for the DOT to manage the ongoing research and may required more DOT personnel to be involved in project oversight.

ARIZONA UNIVERSITY LOCATIONS

Although none of Arizona's three universities currently operates a formalized research center, all three have a civil engineering (CE) department with a program specializing in transportation and faculty who conduct ongoing research. The number of current CE faculty and graduate students at each university are shown in Table 2.

Table 2. Arizona University Civil Engineering Faculty and Graduate Students

UNIVERSITY	# CE FACULTY	# GRADUATE STUDENTS
Arizona State University	12 *	25 *
Northern Arizona University	6	3 **
University of Arizona	8	30

* ASU totals are for those faculty and students in transportation-related fields. Additional CE faculty and graduate students are available in the structural, environmental, and geotechnical fields.

** NAU does not currently have a graduate program, but will begin one in fall 1998 with two or three graduate students expected.

In addition to the CE faculty and students available at each university, various other departments and disciplines would be available and interested in pursuing transportation-related research. For example, the 1994 ASU CATSR-affiliated faculty included 16 different departments and 42 faculty. Affiliated departments included civil engineering, electrical engineering, psychology, decision and information systems, geography, mechanical and aerospace engineering, biochemistry, computer science, aeronautical technology, planning, business, environmental research, exercise science, math, construction, and industrial and management systems engineering. All but two of those 1996 CATSR faculty are still at ASU; with the addition of at least three new faculty who have expressed an interest in transportation research. [8] All three CE departments have expressed the desire to have a transportation research center located at their university.

COOPERATIVE AGREEMENT

The Texas Transportation Institute (TTI) has provided their example of what a cooperative research program should include.

- The elements of a cooperative research agreement should include:
  - The research program should be developed jointly with input from all parties.
  - The sponsoring and performing agencies should share in the cost of the research so that each has a stake in the research and products produced.
  - Conduct of the research must have sufficient involvement from the sponsoring agency to assure that the original intent of the research objectives is being pursued.
- In a cooperative program, the DOT should expect:
  - That the contracted research will be performed on schedule and within budget in accordance with an approved work plan.
  - That the quality of the research and its resulting products will be of the highest professional quality.
  - That the university will have or can make available professionally qualified staff to address the identified priority problems in a timely manner.
  - That the facilities and equipment of the university will be available for use in the cooperative program.
  - That the university will develop a pool of graduate professionals qualified to become potential employees of the DOT.
- In return, the university should expect:
  - That the funding for the program will have continuity without major reductions from year to year so that top quality staff can be retained and expertise improved from year to year.
  - That the DOT/university relationship be considered a partnership rather than strictly a contractual arrangement, so that issues arising during the course of the research can be resolved effectively and efficiently.

- That the administrative requirements of the program be kept as simple as possible in order to minimize costs and program delays.

BASIC AGREEMENT

In states where a formal cooperative research arrangement exists between the DOT and one or more universities, a written agreement specifying the rights and responsibilities of each party is usually in effect.

In several cases, the authority for the cooperative research agreement is specified by a legislative act which authorizes state transportation research to be conducted by a particular university. Examples include Purdue University in Indiana and the University of Tennessee. In other instances, the agreement is entered into pursuant to general legislation authorizing interagency agreements. This is the case in Washington with the agreement between the Washington DOT, the University of Washington, and Washington State University. [1] An example of the interagency agreement which formed the Washington State Transportation Center (TRAC) is shown in Appendix G.

In every known case so far, DOT-university agreements are limited to public institutions. Those states which conduct research with non-state universities and private institutions do so on a individual contract basis. In the NCHRP 1996 study, 33 of the 42 states responding to the survey (79%) reported having some type of basic agreement with universities. [6]

A basic agreement is not a contract with the university, but rather an understanding between the state and the university of "boiler plate" terms. There are two types of basic agreement - a memorandum of understanding which is usually less complex and an actual basic agreement which is more detailed. Appendix E shows the memorandum of understanding which established the Colorado Transportation Institute (CTI) in 1992. Participants to this agreement were the Colorado Department of Transportation (CODOT), the Colorado School of Mines, the Colorado State University, the University of Colorado, the University of Colorado at Denver, and the University of Southern Colorado. Although the agreement was not renewed on its expiration date due poor response from the universities, it can provide an example to states of where to start when creating their own basic agreement, and perhaps as CODOT says, "an example of what didn't work".

An example of a basic agreement which is currently working is shown in Appendix F. This is the agreement including addendums between the Iowa Department of Transportation (IDOT) and Iowa State University's (ISU) Center for Transportation Research and Education (CTRE). The agreement spells out the responsibilities of each party and the addendums cover the development support and administrative elements of the agreement. This arrangement has proven very successful for Iowa to date, although they have come to realize that the funding provisions for the director of CTRE whose salary is split between IDOT and ISU, could make it difficult to recruit a successor to the current director when that becomes necessary.

Another example of a basic agreement is shown in Appendix H. This is the basic agreement between Washington DOT and the University of Washington. Again, this agreement details the responsibilities of each party, while taking care to state that it is not a guarantee that any specific number of research projects will be assigned to the university. The award of research projects is accomplished through a task order which is explained below. This basic agreement includes references to the format for writing the working papers and final and interim reports and the requirement to comply with Title 6 of the Civil Rights Act of 1964, although those portions are not shown in this report. As with Iowa, Washington's TRAC executive director and co-directors divide their time and salary between TRAC and their respective organizations; however, they have found no difficulties with the arrangement, and the relationship between all three organizations has been very successful.

TASK ORDER

Once the basic agreement is established between the DOT and the university(s), awarding research projects can be accomplished several ways. The two most common include issuing either RFPs or task orders. As reported earlier in this report, nearly two-thirds (57%) of states issue RFPs to universities only. Several of those states (e.g., Colorado, Florida, Minnesota, Washington, and Wyoming) also issue sole source awards in addition to the RFP process. Sole source awards allow the DOT to award contracts without solicitation of bids. This method has several advantages:

- This technique saves considerable time in the contracting process;
- Advantage can be taken of the beneficial experience that the DOT has had with a university in the past and the relationship can be enhanced over time;
- A search for additional contractors may not be warranted;
- Emergency investigations often cannot be handled any other way.

A sole source award is accomplished by issuing a task order to a university with which the DOT already has a basic agreement. The addition of the task order to the basic agreement forms a contract. The task order is usually only a few pages in length and could contain the scope of work or reference to an attached document, the budget for the research, the principal contacts at the DOT, the principal investigator, and reference to the terms of the basic agreement. [6] A copy of Washington's task order is shown in Appendix I.

BENEFITS

According to comments received from survey responses, establishing a cooperative agreement between ADOT and all three in-state universities could provide many benefits toward promoting transportation research and learning in the state of Arizona. These include the following:

- A cooperative agreement would promote a partnership and closer relationship between ADOT and the three universities while still allowing for competitiveness among the universities.

- An agreement including all three universities would allow for combining talents and expertise at the universities to form a consortium for appropriate projects which would increase learning and improve the product provided, as well as provide added manpower if necessary. A step in this direction has already been taken with the three Arizona universities establishing a transportation research partnership agreement. A copy of this agreement is shown in Appendix J.

- An agreement which is written with the joint consultation of ADOT and all three universities should provide a "win-win" situation with no university feeling left out of the research process.

- Adding a provision for appropriate funding from both ADOT and the universities within the agreement allows for stability of the research center(s) over the long-term.

- The knowledge that the university will be awarded ADOT projects (although not guaranteed of how many projects or how much funding) allows the school to attract top faculty and students which increases learning and improves the final product.

CHALLENGES

There were truly no disadvantages cited by survey respondents in establishing a cooperative agreement between ADOT and Arizona's state universities. However, there were challenges cited and several issues which other states have found must be included in the agreement in order to prevent future problems. These are as follows:

- Arriving at an agreement which is acceptable to all three universities and ADOT could be a long process, although it should prove to be a time-saver in the long-run.

- The agreement must be written to allow ADOT flexibility in awarding research projects to entities other than the universities if warranted.

- The agreement, while providing some funding for continuity or a "presence" as in the Washington case, must not allow the universities to feel they are "guaranteed" a specific amount of funding for research projects.

- The agreement must allow for competitiveness while maintaining harmonious relations between the universities in order to provide the best product for ADOT.

- The agreement should provide a means for ADOT to monitor the progress of research awards and contain an accountability clause for the universities.

CONTRACT MANAGEMENT

Over the years, state DOTs, although strongly believing in the benefits of maintaining partnerships with the universities, have continually complained about some difficulties experienced in contracting with these same universities. The most common problems stated have been difficulties monitoring the progress of the research, that universities have not been held accountable for meeting deadlines and maintaining the original scope of the project and implementation of research results is often difficult if not impossible to achieve. All of these problems can be avoided if the basic agreement is written properly as stated above, and a process for monitoring the progress of the research is established. A good resource in establishing such a process is available from the National Cooperative Highway Research Program (NCHRP). Their report "Synthesis of Highway Practice 231 - Managing Contract Research Programs" specifically targets these challenges and offers ways to avoid them, including chapters on selecting a contract program, negotiating a contract, monitoring the contract, and implementation of contract results. [6]

Entering into contract negotiations with a clear understanding of goals and the foresight provided by others should allow ADOT and the universities to arrive at a basic agreement which will prove only beneficial to all parties involved. In addition, allowing for flexibility in that agreement with modifications as needed, will ensure that it remains viable over the long-term.

PRIVATE SECTOR FUNDING

An effort to find sources of research funding in addition to the traditional state and federal funding programs, prompted ADOT to question survey respondents as to whether they solicit private sector involvement and funding in their research centers, and if they do, whether this additional funding allowed the center to be self-sufficient. Over 75% of the states responding to the survey (31 out of 41 responses) indicated they have some private sector involvement in their program. None of the states, however, receive enough funding from the private sector to be self-sufficient. Comments regarding this involvement were the same from all respondents.

- Most private sector involvement is unsolicited. The private sector firm generally approaches the DOT or university research center with research ideas.

- Few centers actively solicit private sector involvement except for occasional projects which would obviously benefit some area in the private sector.

- Few hard dollars are provided. Most private sector involvement is in the form of materials, equipment, and services which may be provided through serving on advisory boards or conducting research.

According to financial summaries in the "1995 CUTC Member Profile", contributions from private sources and industry ranged from less than 1% to as much as 18% (at Northwestern University in Illinois) for 1994. [4] Survey data reiterated these percentages. The Texas program at TTI is often approached by the private sector due to the success of their center. They receive the largest dollar amount (between $1.5-3 million annually), yet this accounts for just 5-10% of their budget. Potential sources of private sector funding indicated by survey respondents include shippers and carriers (e.g., trucking, airlines, rail), and trade organizations such as the American Trucking Association or the automobile industry. Four of the responding states are making an attempt to increase the amount of private sector funding in their programs.

- The Center for Microcomputers in Transportation at the University of Florida's Transportation Research Center receives substantial support which allows this one segment of the center to be self-supporting. A large portion of the University of Florida's T2 program is supported through registration fees and private sector sponsorship of workshops. All research at the center, however, is publicly supported.

- Minnesota works closely with the private sector for its ITS deployment and field test ventures, but this funding source is not a major component for the rest of the research budget.

- The LTRC at Louisiana State University recently established the LTRC Foundation as a non-profit organization in an attempt to partner with the private sector for narrow, focused goals. They don't intend for this funding to be for their operational budget. At the present time, solicitation is being conducted to expand their training facilities.

- The Institute of Transportation Studies at the three University of California campuses have a corporate affiliate program with annual fees, industry internships, industry-sponsored research, and industry membership in research consortia. Even so, this involvement is "somewhat haphazard" and not as much as they would desire. They are attempting to rethink and redesign the partnerships.

One other university research center which has a corporate affiliate program is the Massachusetts Institute of Technology. Although MIT did not respond to ADOT's survey, an article describing their program was carried in Traffic World in the March 13, 1995 issue. MIT states that they began their corporate affiliate program in 1981 in order to establish an active partnership between the center and participating carriers and shippers. Affiliates provide annual financial support of $15,000 per company which is used for student assistance, new research, and education programs for industry. The member companies take an active role in center programs, including participation in frequent seminars on "hot" topics and decision-maker forums for senior executives. The affiliate employees are also guaranteed a certain number of seats at the center's popular summer course on logistics. Top affiliate executives meet annually for an educational and discussion program. The article listed the 1995 members as follows: [9]

American President Lines
AT&T
Bose
British Airways
British Railways
Burlington Northern
Canadian National Railways
Caterpillar
Chemical Leaman Tank Lines
Conrail
Consolidated Freightways
CSX Transportation
Digital Equipment
Dow Chemical
Du Pont
Federal Express
Flota Mercante Grancolombiana
Gillette
Goodyear Tire & Rubber
International Business Machines
LogiCorp
Maersk
Mars
Norfolk Southern
NYK Line
Procter & Gamble
Roadway Services
Ryder System
Sea-Land Service
Sema Group
3M
Unilever
Union Pacific
United Parcel Service
U. S. Postal Service
Volkswagen
Yellow Freight

Although this funding from the private sector amounts to over $500,000, it still accounts for only approximately 12% of MIT's total expenditures according to the "1995 CUTC Member Profile". [4]

One issue cited by several survey respondents regarding joint public and private sector research involves the issue of patent or copyright complications. The three Arizona universities are currently revising their intellectual property policy. A draft of the proposed policy is available on the internet at http://researchnet.asu.edu/techcoll/policy/. Those interested are requested to review the policy and submit comments. Once the universities are satisfied with the policy, it will be sent to the Board of Regents for ratification.

RESEARCH CENTER BUDGET

The cost to establish and run a transportation research center at one of the state's universities would be highly dependent upon the model used to establish the center. Since it has been seen, however, that the private sector does not appear to account for a large portion of a center's budget, funding sources must initially come from the legislature, the state DOT, and/or the university(s) (either directly or through various grants obtained). Many states indicated that the transportation research center is highly dependent upon the DOT to supply research projects for approximately the first five years. During that time, the reputation of the center is expanded and its ability to obtain funding and projects from other sources increases.

One feature which is constant among all states which have productive cooperative programs is the continuity of funding. This does not mean that the funding must be large (e.g., Washington DOT's annual $60,000 contribution to TRAC) or even that a set amount is guaranteed from year to year. What it does mean, however, is that either by practice or written agreement, a commitment has been made by the state DOT to sustain a level of support sufficient to elicit a commitment on the university's part to devote sufficient faculty and other resources to meet the highway agency's needs. [1] Availability and stability of funding, therefore, are critical during the first years of a research center's existence.

The actual costs to establish a center must be negotiated with the university where the center is to be located. Space and personnel costs can range from nothing (where they are counted as a portion of the university's funding contribution) to a negotiated cost per square foot for rent or personnel salaries which the center pays to the university. The following information is provided in order to compare existing programs in other states and for use as a basis in establishing a similar program in Arizona.

DOT EXPENDITURES

Funding available to finance the research activities of a state DOT may be obtained from a variety of categories as listed below.

SPR (Federal) - The Federal-Aid Highway Act of 1962 requires that 2 percent of all federal aid apportionments to each state be available for planning and research. These funds are designated as SPR (State Planning and Research) funds, and must be matched by the state based on the matching ratio established by federal law. Most states' research efforts are aided by funds from this source.

State Funds - Some studies which have limited scope, local interest, or a shortage of federal funds are financed with state funds.

NCHRP - The National Cooperative Highway Research Program (NCRHP) is a pooled-fund program directed toward problems of national significance sponsored by the state DOTs

and the Federal Highway Administration (FHWA), and administered by the Transportation Research Board (TRB). The program is supported by individual state DOTs with SPR funds based on a certain percentage of their SPR program. These funds do not require a state match. Studies conducted through this program are usually high cost and are identified through an annual solicitation through the American Association of State Highway and Transportation Officials (AASHTO).

Pooled-Fund Projects - When widespread, regional or national interest is shown in a significant problem, research studies of major importance may be conducted on a cooperative basis by several states, the FHWA, and third parties (contractors, universities, etc.). These studies may be conducted using SPR funds without state matched funds. The FHWA generally acts as the contracting agency for the participating states. An advisory committee composed of representatives of each participating state and of the FHWA is established to provide overall project direction and permit consideration of the cooperating states' views.

R&D Management Option - Recent national research objectives include allowing the states more freedom in managing research activities. The R&D Management Option was created to encourage this. Upon approval by the FHWA, which is based on a satisfactory review by FHWA staff of a state's ability to operate independently and efficiently, the state DOT may initiate federally-funded SPR projects without prior FHWA approval. To obtain this approval, it is necessary to have an effective research advisory committee, an up-to-date research policy, and a detailed research manual.

Nationally Coordinated Program (NCP) - The NCP, created by the FHWA, focuses on subjects of highest national priority. These projects are coordinated by NCP management, and are usually long-term, pooled efforts. Current areas of interest include ITS, intermodal transportation systems, seismic research, commercial vehicle safety, international outreach, and education and training programs.

The "Synthesis of Highway Practice 231 - Managing Contract Research Programs" identified the 1994 funding sources of the state DOTs as shown in Table 3. [6]

Table 3. 1994 DOT Funding Sources

	FUNDING SOURCE (in $1000)				FUNDING SOURCE (in $1000)		
STATE	*SPR*	*STATE*	*OTHER**	*STATE*	*SPR*	*STATE*	*OTHER**
Alabama	1375	1000	81	Nebraska	922	231	
Alaska	330	82		Nevada	296	80	
Arizona**	1179	350		New Hampshire	410	60	
Arkansas	307	170	700	New Jersey	3238		710
California	7000	4260		New York	3116	1047	661
Colorado	2000	600		New Mexico	360	120	480
Connecticut	2288	554	316	North Carolina	1430	383	263
Florida	2600	2400	100	North Dakota	500	100	
Georgia	1898	475	967	Ohio	3128	622	
Idaho	217	26	48	Oregon	1026	415	271
Illinois	1690	1434		Pennsylvania	2900	750	275
Indiana	3120	1300	105	Rhode Island	449	112	
Iowa	1410	1850	1600	South Carolina	1036	155	
Kentucky	1710	1208	690	South Dakota	640	450	
Louisiana	2626	1262		Tennessee	1500	500	
Maine	280	260		Texas	8000	9000	5000
Maryland	1117	461		Utah	659	472	800
Michigan	2100	3800		Washington	2219	3126	608
Minnesota	1112	6009	1300	West Virginia	598	150	484
Mississippi	968	242	650	Wisconsin	1200	240	
Missouri	1750		67	Wyoming	560	124	270

Notes:
*Other sources of funds include: ISTEA, FHWA, Industry, State, IVHS, FAA, NSF, LTAP, Safety (402)
**Arizona data is for fiscal year 1998
Source: NCHRP Synthesis of Highway Practice 231 - Managing Contract Research Programs
Although Virginia DOT (VDOT) was not included in the above report, the Virginia Transportation Research Council (VTRC) 1994 Annual Report gives the income and expenditure information as shown in Figures 5 and 6. [10]

Figure 5

1994 Virginia Research Funding Sources

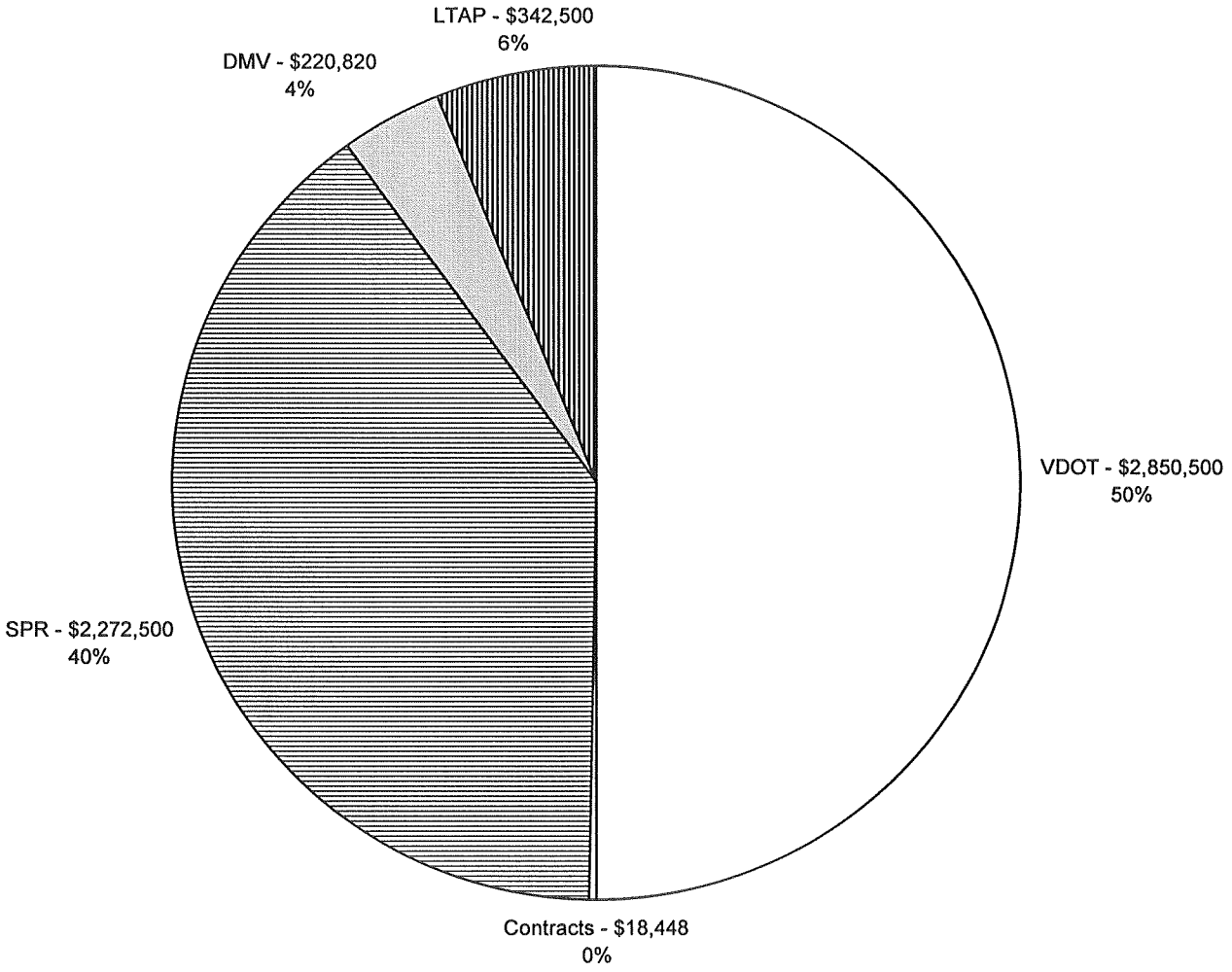


Figure 6

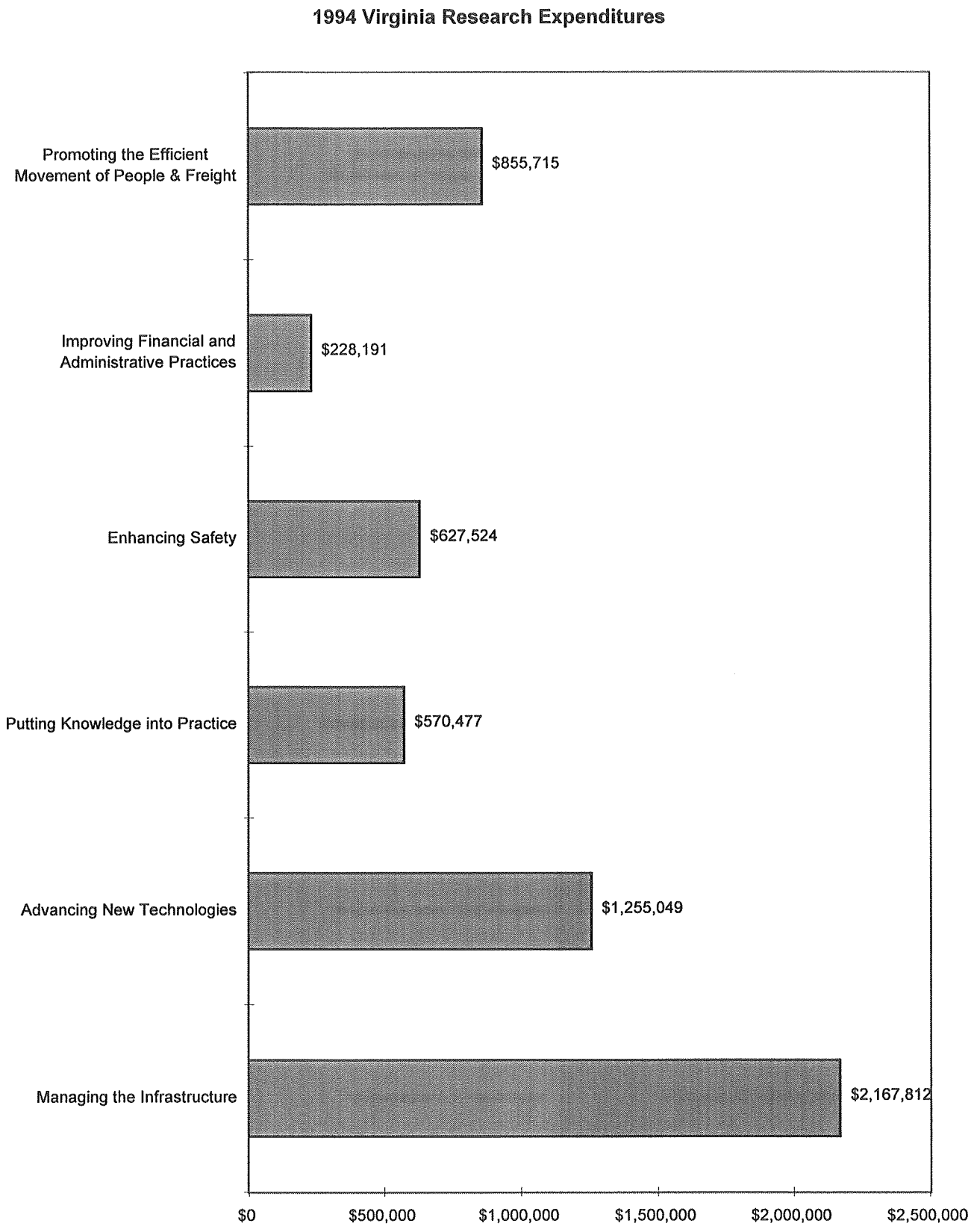

1994 Virginia Research Expenditures
Promoting the Efficient Movement of People & Freight
$855,715
Improving Financial and Administrative Practices
$228,191
Enhancing Safety
$627,524
Putting Knowledge into Practice
$570,477
Advancing New Technologies
$1,255,049
Managing the Infrastructure
$2,167,812
$0
$500,000
$1,000,000
$1,500,000
$2,000,000
$2,500,000

Figure 7

1996 Minnesota Research Funding Sources

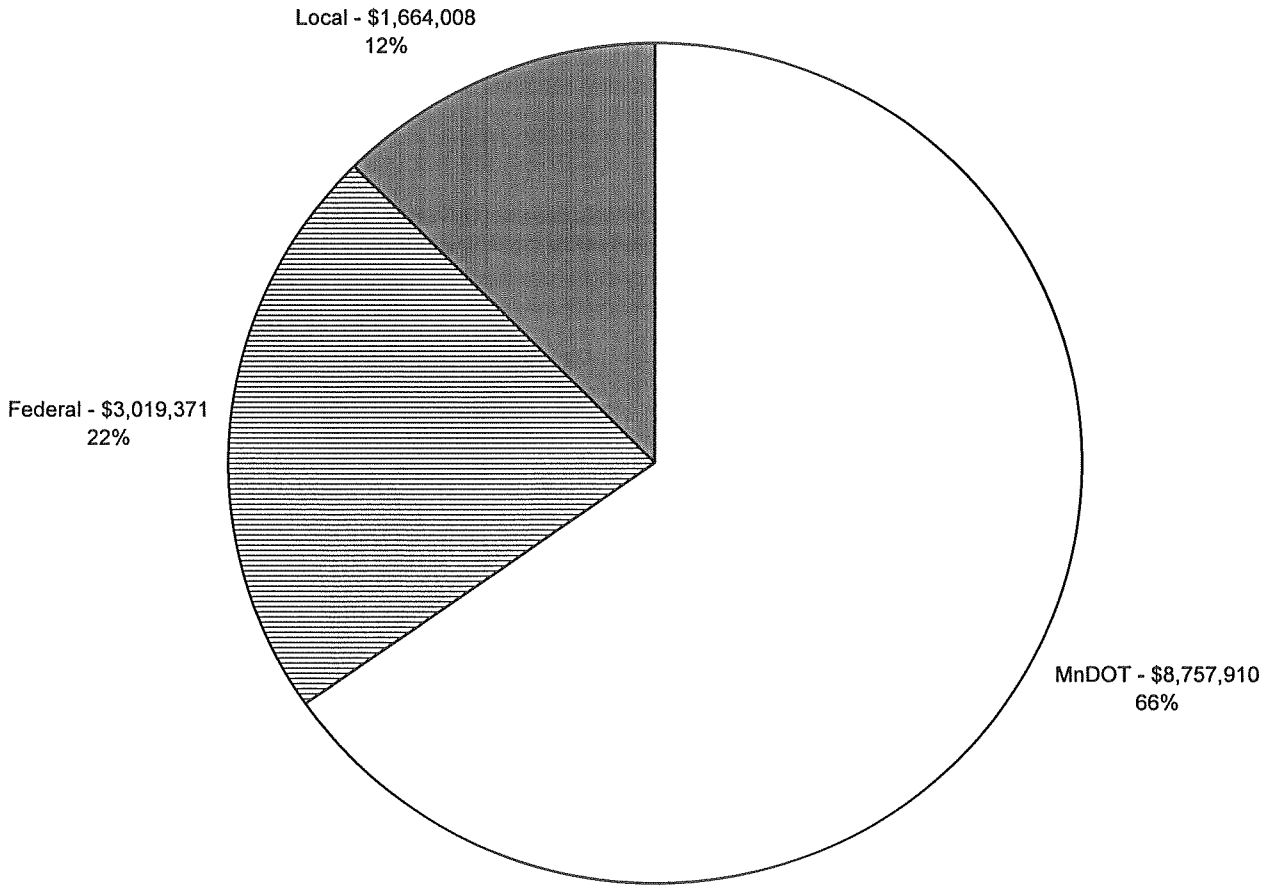
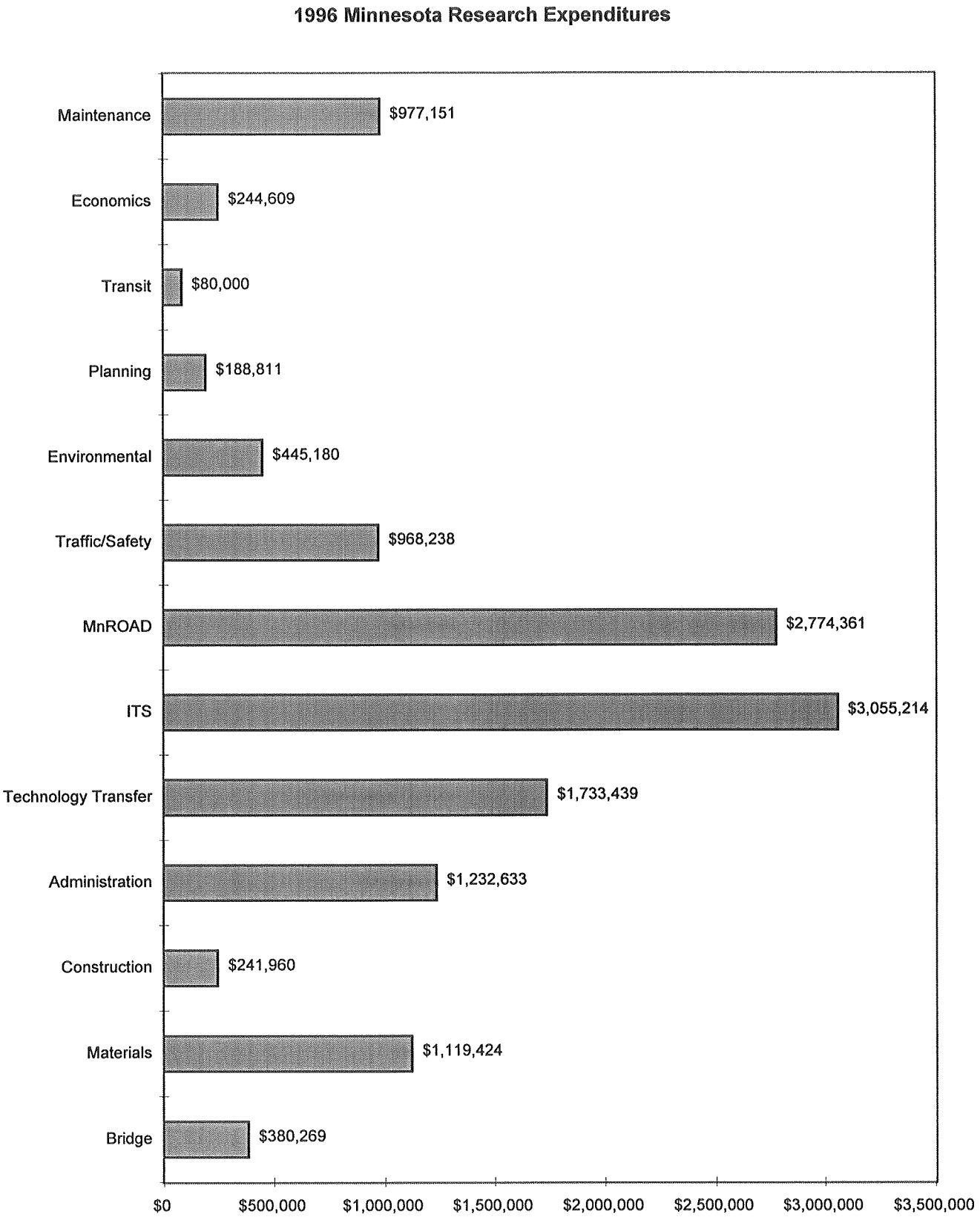


Figure 8


1996 Minnesota Research Expenditures
Maintenance
$977,151
Economics
$244,609
Transit
$80,000
Planning
$188,811
Environmental
$445,180
Traffic/Safety
$968,238
MnROAD
$2,774,361
ITS
$3,055,214
Technology Transfer
$1,733,439
Administration
$1,232,633
Construction
$241,960
Materials
$1,119,424
Bridge
$380,269
$0
$500,000
$1,000,000
$1,500,000
$2,000,000
$2,500,000
$3,000,000
$3,500,000

By comparison, Arizona's 1998 funding sources included a carry over SPR budget of $3,176,580 plus an additional $1,179,000 in new funding, for a total SPR budget of $4,355,580. Expenses for the Arizona DOT's research center, ATRC, for the fiscal year through December 1997 are shown below in Table 4.

Table 4. 1997 ATRC Expenditures

Administrative	
ADOT-funded (6 personnel)	$138,236
Federally-funded (3 personnel)	48,607
Subtotal	$186,843
Research & Research-Related	
Professional Services(consultants, universities, student researchers)	$1,374,815
ADOT	233,106
Federally-funded researchers	2,887
Subtotal	$1,610,808
Total Research Expenses *	$1,797,651
Note: These expenses do not include building overhead which is included in a different ADOT funding category.	

UNIVERSITY EXPENDITURES

The 1995 CUTC Member Profile provides the 1994 financial summaries of active CUTC institutions. The financial data is broken into five subheadings as shown below in Table 5. [4]

Table 5. 1994 CUTC Financial Summaries

STATE	UNIVERSITY	TOTAL GRANT & CONTRACT EXPENDITURES	DIRECT MONETARY SUPPORT FROM UNIVERSITY	LEGISLATIVE APPROPRIA-TIONS	PRIVATE/ INDUSTRY CONTRIBU-TIONS	MARKET VALUE OF EQUIPMENT/ COMPUTER SOFTWARE DONATED
AR	University of Arkansas	$1,166,595	$260,307			
CA	University of California, Berkeley	$8,000,000	$827,000			
CA	University of California, Davis	$4,040,176	$73,837	$46,700		$20,000
CA	University of California, Irvine	$6,000,000	$314,000			
FL	University of Central Florida	$350,000	$12,500			
FL	University of Florida	$2,027,054	$21,812			
FL	University of Southern Florida	$4,800,000		$1,500,000		
GA	Georgia State University	$110,000	$90,000			
IA	Iowa State University	$4,000,000	$60,000			$15,000
IN	Purdue University	$1,744,754			$120,000	
KS	Kansas State University	$975,000	$20,000		$150,000	
KY	University of Kentucky	$3,983,100		$190,000		
LA	Louisiana State University	$1,689,000				
MA	Massachusetts Institute of Technology	$4,725,000	$78,592		$570,000	
MI	University of Michigan	$10,957,183	$692,609			
MI	Wayne State University	$180,000	$7,500			
MN	University of Minnesota	$3,200,000		$717,000	$75,000	
NE	University of Nebraska, Lincoln	$409,258	$444,500			
NV	University of Nevada, Las Vegas	$600,000				
NV	University of Nevada, Reno	$696,000				
NY	The City University of New York	$1,285,120	$137,000			
NY	Cornell University	$750,000				
NY	Polytechnic University of New York	$600,000	$25,000			
NY	Rensselaer Polytechnic Institute	$1,200,000				
NC	Duke University	$250,000	$1,000			
NC	North Carolina State University	$4,540,789	$452,898			$50,000
ND	North Dakota State	$1,961,692		$200,000		

	University					
OR	Oregon State University	$1,500,000	$42,421			
PA	Pennsylvania State University	$6,254,340	$433,741			
PA	University of Pennsylvania	$260,000		$40,000		
TN	Tennessee Technological University	$108,935	$4,800			
TN	University of Memphis	$250,000	$15,000			
TN	Vanderbilt University	$864,000	$17,000		$6,800	$12,000
TX	Texas A&M University	$19,311,643		$1,957,227		
TX	University of Texas	$8,080,115	$50,262			$15,000
VA	VA George Mason University	$1,800,000	$100,000		$30,000	
VA	University of Virginia	$575,000				$50,000
VA	Virginia Polytechnic Institute & State University	$1,703,442	$52,256		$126,526	
WA	University of Washington	$6,000,000	$60,000			
WV	West Virginia University	$100,000	$10,000			
Source: 1995 CUTC Member Profile						

Arizona State University's research center, CATSR, reported 1994 total grant and contract expenditures of $600,000 and direct monetary support from the university of $150,000. [4] A breakdown of CATSR expenses is shown in Figure 6. [8]

Table 6. 1994 CATSR Expenditures

Personnel	$35,449
Operations	20,378
Travel	12,095
Capital Equipment	4,255
Research & Projects	439,373
Total Expenses	$583,727

POTENTIAL FUNDING SOURCES

In addition to the funding sources detailed above under the DOT Expenditures category, there are many other sources which provide funding for research projects. Many of these sources maintain a web site on the Internet which describes the program and lists projects for which they are currently requesting proposals. Several of these are listed below.

National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP) project statements are available at http://www2.nas.edu/trbcrp/rfps.html. Research problem statements can also be submitted over the Internet to TCRP at http://www.apta.com/tcrp/input.html.

The Research and Special Programs Administration (RSPA) is one of nine major agencies of the United States Department of Transportation. RSPA is the Department's research, safety, and transportation systems administration, and is responsible for addressing transmodal issues relative to the safe, effective, and efficient transportation of people and goods throughout the world. In contrast to the other Department operation administrations which focus on specific sectors of the US transportation system, RSPA's mission concentrates on the system as a whole. A list of current RFPs can be found on the Internet at http://www.rspa.dot.gov/contracts.html.

The Federal Transit Administration is a possible source of funding for research related to transit issues. Their web site is http://www.fta.dot.gov/.

The National Transportation Products Evaluation Program (NTPEP) pools the professional and physical resources of AASHTO's member departments to test materials of common interest. Information on this program can be found on the Internet at http://www.aashto.org/prog_svcs/ntpep/.

The Institute of Transportation Engineers (ITE) lists requests for proposals at http://www.ite.org/positions/rfp.htm.

A list of ITS RFPs and Requests for Information (RFIs) can be found at http://www.itsonline.com/rfp/.

Other potential sources of research funding (although they often compete for proposals as well) include: the National Asphalt Pavement Association (NAPA) which represents the interests of the Hot Mix Asphalt (HMA) Industry; the American Trucking Association; and the automobile and air industries.

COMMENTS

The survey conducted by ADOT requested respondents to provide any additional comments which they felt would benefit Arizona in its research into the organizational/structural relationship between DOTs and state universities in conducting transportation research. The comments received were very similar in the advice offered. The following is a summary of those comments.

> The effectiveness of a research program is related to the commitment to research by upper management in the highway agency. Upper management must see research as a means of building expertise and continuing education of staff and new employees in the long-term, as well as improving today's transportation problems. The most important expression of this is the personal involvement of senior management in the research policy board or executive committee which reviews and approves the agency's annual research program. Active participation by senior executives not only provides a ready communication channel between the research function and the policy and budgeting divisions of the agency, but it is also made clear to middle managers and their staff that research is considered by top management to be an important activity in fulfilling the agency's mission of providing safe, effective, and efficient highway transportation to the people of the state. [1]

> No two states, DOTs, or universities are alike; therefore, the relationship must be tailored to local conditions and what works best for the organization and current management. How the research relationship is organized should not be the main issue since it must remain flexible in order to survive long-term. The main concern should be the development of a solid mission statement which can help the relationship remain true to its goals through personnel and organizational changes. Convening a meeting with several states with better-known research programs and including representatives from ADOT and the three universities should be considered in order to explore the "best" relationships in more depth.

> The relationship must be a partnership which fosters mutual trust. All organizations which will be a part of the final relationship must be consulted and have input into the organizational structure from the beginning in order to have total commitment from all involved.

> University participation on the research policy board (whether in voting or non-voting capacity) is a common feature of most of the programs surveyed.

> Don't favor an exclusive arrangement where a university is "guaranteed" all DOT research. A competitive environment significantly strengthens the university's ability to propose and conduct research for the DOT and all other requesters of research. Neither the DOT nor the university(s) should fear a free, fair, merit-based competition.

The ultimate goal of a state transportation research program is to improve transportation either through the DOT or through local transportation programs. The DOT's primary goal is to conduct applied research. Since the DOT is funding this research, they must maintain program oversight in order to achieve this goal. Requiring the researchers to include an implementation plan in their proposal helps to keep the researcher focused as well.

Conduct periodic workshops at which the DOT, the universities, and private industry can discuss what research needs appear to be of utmost importance. Allow the universities (and private industry) to tell the DOT what they can do to solve tomorrow's problems, but don't promise which research (if any) will be conducted.

In a 1988 presentation at the National Workshop on Highway Research, current Texas Department of Highways Engineer-Director Raymond Stotzer provided the following elements which have contributed to making the Texas program successful. He called them the ten commandments of research, Texas-style. [7] These "commandments" are offered below.

1. Thou shalt not stray from the real world in selecting research problems. Texas uses 95 percent of its research budget to conduct applied research. Only five percent is used for basic research in areas such as materials properties or management and policy studies. All state DOTs mentioned the necessity of conducting applied research.

2. Thou shalt not duplicate. All similar research should be carefully coordinated, not only within the state, but also nationwide. This is where the T2 programs across the country come in. Research reports are disseminated nationwide and can also be entered into a computer system which has access to 120 different databases in all fields, including traditional transportation databases. This allows research to build on previous research rather than duplicating it.

3. Thou shalt monitor progress of research and redirect its course if necessary. Remember always that research must speak directly to a real problem. This issue is critical in ensuring the research meets the DOT's needs. Lack of monitoring by the DOT and the resulting dissatisfaction in the research product is one of the difficulties mentioned by many DOTs.

4. Thy results shall be timely. Although it is not always possible to set an absolute time limit on a project, the results do need to be obtained while they are still relevant to an existing problem. A project due date should be established and periodic updates by the researcher should keep the DOT informed as to its progress. Linking contract payment installments to completed research tasks helps in this regard.

5. Thou shalt ensure that results are simple and usable. The final research report must be understandable by those who must use the results.

6. Thou shalt provide continuity in the research program. The constant use of university programs by the DOT ensures the university of a consistent level of funding. This allows research staff to be maintained in many fields. It allows the DOT to know the university's capabilities, and allows the university to understand the DOT's problems.

7. Thou shalt fully document reports for dissemination, and use them later as a beginning for further research. This relates back to preventing duplication of efforts. The final research reports should be disseminated to as many people and agencies as possible in order to aid them in advancing their knowledge of the subject as well.

8. Thy research shall have the potential to be cost beneficial. To be cost effective, research should do one or more things: increase safety, lower costs, reduce waste, increase personnel efficiency or production, eliminate unneeded work, improve working conditions, methods or equipment, improve operations, or extend service life. Many DOTs have found that the benefit-cost for research is from 20:1 to 30:1. Stotzer believes that Texas has had successful projects where the savings could endow the research program for perpetuity.

9. Thy research shall not only seek to solve problems, but also find cost-effective new methods. The research conclusions must be achievable. A solution which is very expensive cannot be implemented by a department with increasingly tightening budgets.

10. Thy researchers shall be available for assistance in implementation of the results. Many DOTs are coming to see that involving the researcher in the implementation of the research results benefits both the researcher in understanding the DOT's needs and the DOT employees who are not left to figure things out for themselves.

These ten commandments have helped the Texas program attain its many accomplishments because they have developed a system which puts them to use and has worked well for Texas for many years.